THE HETCH HETCHY WATER SUPPLY FOR SAN FRANCISCO, 1912

REPORT BY JOHN R. FREEMAN

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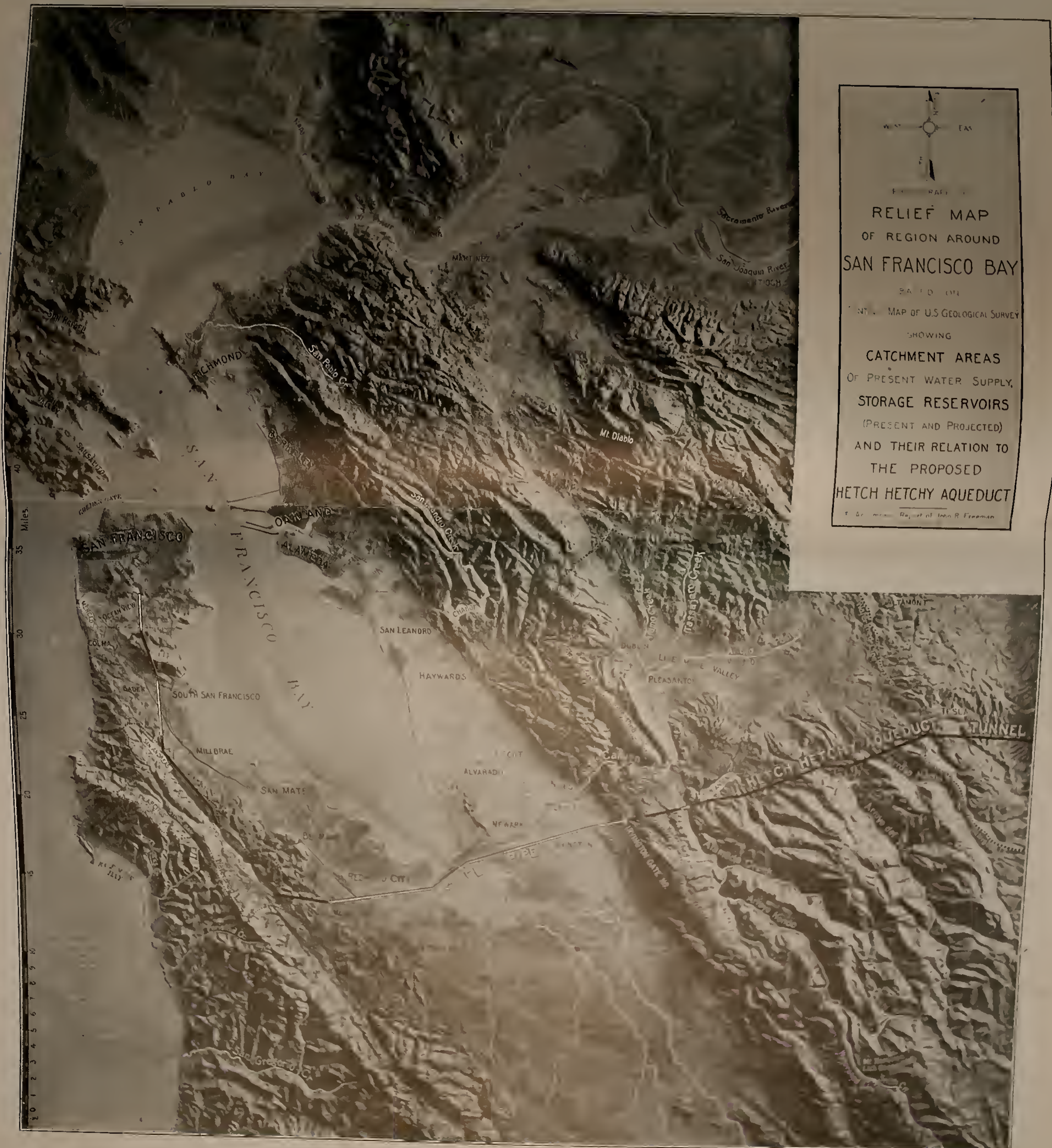

RELIEF MAP
OF REGION AROUND
SAN FRANCISCO BAY
BASED ON
MAP OF U.S. GEOLOGICAL SURVEY
SHOWING
CATCHMENT AREAS
OF PRESENT WATER SUPPLY,
STORAGE RESERVOIRS
(PRESENT AND PROJECTED)
AND THEIR RELATION TO
THE PROPOSED
HETCH HETCHY AQUEDUCT

To Accompany Report of John R. Freeman

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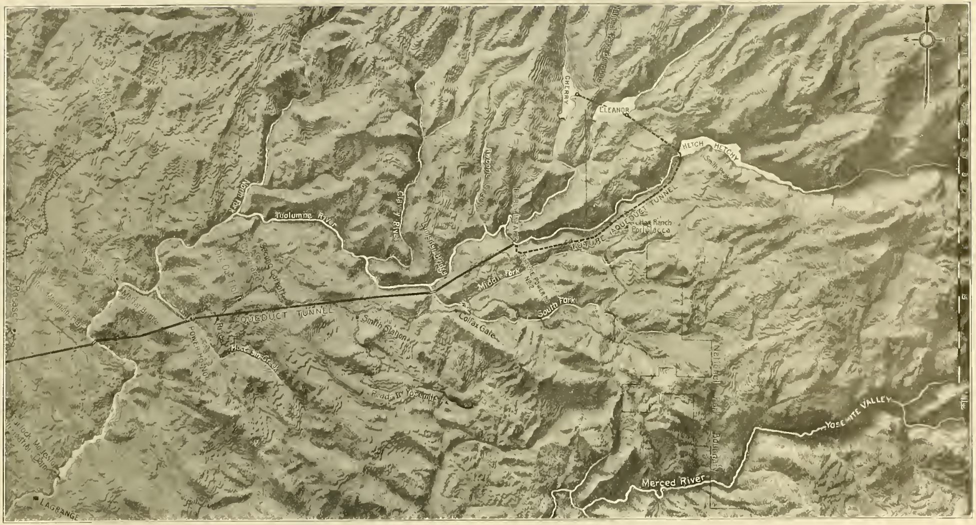

HETCH HETCHY
Smith Peak
ELEANOR
CHERRY
National Park Boundary
FUTURE AQUEDUCT TUNNEL
Hog Ranch
Portulacca
EARLY INTAKE
FUTURE POWER HO. No. 2
Middle Fork
South Fork
Colfax Gate
Rawbone Creek
Lumsden Bridge
Clavey River
Tuolumne River
North Fork
Second Garrotte
Groveland
Big Oak Flat
AQUEDUCT TUNNEL
Smith Station
Road to Yosemite
Moccasin Creek
Priest
POWER HO. No. 1
Mortar Bridge
Red Mountain Bar
Jacksonville
Rosasco
Chinese
Railroad
SONORA
Turlock Modesto Irrigation Dam
LAGRANGE
YOSEMITE VALLEY
Merced River
National Park Boundary
Miles
W
E

July 14, 1912.

The Advisory Board United States Army Engineers,
San Francisco, Cal.

Gentlemen—We are filing today with your Board the report of Mr. John R. Freeman on the proposed use of a portion of the Hetch Hetchy, Eleanor and Cherry Valleys within and near to the boundaries of the Stanislaus U. S. National Forest Reserve and the Yosemite National Park. This report is filed in compliance with the terms of a letter to the Mayor of San Francisco from the Secretary of the Interior dated May 28, 1912, and is the result of a two years' personal study on the part of Mr. Freeman, working with a staff of skilled engineers. The work of the engineers under Mr. Freeman is embodied in this report, and he has further analyzed as a basis for his conclusions the studies made by eminent specialists in various branches of hydraulic engineering.

This report treats of the needs of the San Francisco Bay region, and we believe presents in the most comprehensive manner the hopes and the needs of what must be a future metropolitan water district. At a great cost of labor and money San Francisco has tried to meet the spirit of the order of the former Secretary of the Interior as originally issued, and somewhat modified by the present Secretary, and the spirit of your Board's request for light on this important subject.

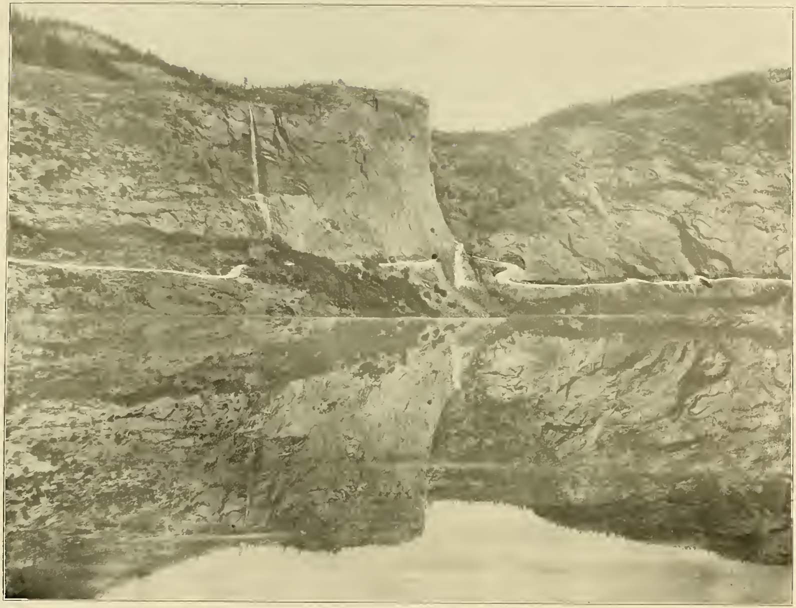
We feel that Mr. Freeman has brought to this task not only his well-known ability and his reputation for loyal service, but has given more than the usual amount of time, energy and enthusiasm in order that the fullest possible presentation of which the case admits might be made.

Whatever may be your Board's conclusion in this matter we cannot close this letter of transmittal without testifying to the obligation of the City of San Francisco to Mr. Freeman and to the intelligent zeal and loyalty which he has brought to his task; and also, in our judgment, his wonderful insight and grasp of what we believe to be the most serious problem confronting our municipality.

Respectfully,

(Signed): JAMES ROLPH, JR.,
Mayor of San Francisco..

PERCY V. LONG,
City Attorney of San Francisco.



THE PROPOSED HETCH HETCHY RESERVOIR.

The depth of water would not lessen the apparent height of cliffs. On the contrary, the reflection would increase it. (Position of scenic road shown by white line.)

To James Rolph, Jr., Mayor of San Francisco;

Percy V. Long, City Attorney of San Francisco.

THE TUOLUMNE WATER SUPPLY.

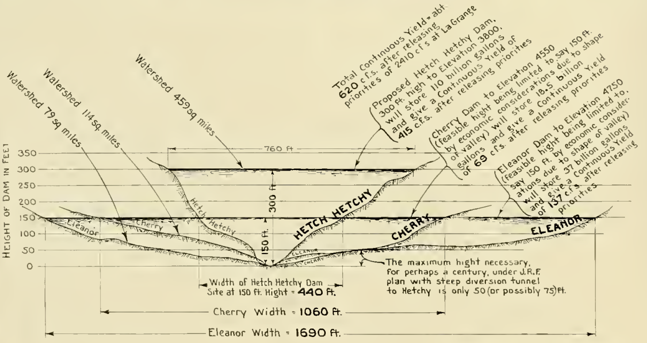
Sirs—At an interview granted by the Secretary of the Interior, the Hon. Walter A. Fisher, at his office in Washington on May 23rd, 1912, upon a presentation of the petition of the Mayor and the Advisory Water Committee for more time in which to make engineering studies and thereby present the city's case in more complete form, after a full discussion between the Secretary, the members of Advisory Board of Army Engineers (Col. Biddle, Col. Cosby, Col. Taylor), and the City Attorney (Hon. Percy V. Long) and the undersigned, the Secretary specified an order of presentation for the City's case which is set forth in a letter to the Mayor of San Francisco, dated May 28th, in which it is stated:

> That on July 15th the City is to file its comprehensive plans (and explanations thereof) as to the proposed use and development of the Hetch Hetchy and Lake Eleanor valleys and watersheds, including the proposed sanitary restrictions and all supporting evidence as to the feasibility of these restrictions; that it is also to file a general outline of the proposed method of conveying water to the city, including power development, etc., all in sufficient detail to present clearly what is proposed and to enable the objectors to the use of the Hetch Hetchy by the City to present their views with respect thereto.

You have asked me to prepare a statement in accordance with the above order, and the following is respectfully presented:

THE HETCH HETCHY DAM SITE.

A deep gorge between high granite cliffs, giving ideal abutments for an arched masonry dam of any height desired.


Watershed 79 sq miles
Watershed 114 sq. miles
Watershed 459 sq miles
Total Continuous Yield = abt 620 c.f.s. after releasing priorities of 2410 c.f.s at La Grange
Proposed Hetch Hetchy Dam, 300 ft. high to Elevation 3800, will store 110 billion gallons and give a Continuous Yield of 415 c.f.s. after releasing priorities
Cherry Dam to Elevation 4550 (feasible hight being limited to say 150 ft. by economic considerations due to shape of valley) will store 18.5 billion gallons and give a Continuous Yield of 69 c.f.s. after releasing priorities
Eleanor Dam to Elevation 4750 (feasible hight being limited to say 150 ft. by economic considerations due to shape of valley) will store 37 billion gallons and give a Continuous Yield of 137 c.f.s. after releasing priorities
760 ft
HEIGHT OF DAM IN FEET
350
300
250
200
150
100
50
0
300 ft.
150 ft.
HETCH HETCHY
CHERRY
ELEANOR
Hetch Hetchy
Cherry
Eleanor
ELEANOR
CHERRY
The maximum hight necessary, for perhaps a century, under J.R.F. plan with steep diversion tunnel to Hetchy is only 50 (or possibly 75) ft.
Width of Hetch Hetchy Dam Site at 150 ft. Hight = 440 ft.
Cherry Width = 1060 ft.
Eleanor Width = 1690 ft.

COMPARISON OF DAM SITES
NATURAL SCALE

Hetchy, by far the largest watershed has much the shortest dam

John R. Freeman, Consulting Engineer
Providence, R. I.
July 10, 1912

A STATEMENT OF THE METHODS OF DEVELOPMENT AND USE OF THE HETCH HETCHY, LAKE ELEANOR AND CHERRY VALLEY BY THE CITY OF SAN FRANCISCO (BY ITSELF OR WITH OTHER MUNICIPALITIES) FOR RESERVOIR SITES AND PURPOSES OF MUNICIPAL WATER SUPPLY, ETC.

Prepared by JOHN R. FREEMAN, Consulting Engineer,
July 15, 1912.

In brief, the City desires to proceed in due course with the following developments under the approval of the Interior Department.

San Francisco and Neighboring Municipalities

For simplicity, in all of the following descriptions the word San Francisco has been used to indicate the group of cities of which that city is the commercial center, comprising substantially all of the cities and smaller communities bordering upon the bay, from San Francisco around southerly, easterly and northerly to Oakland, Berkeley and Richmond, some twenty-six municipalities, comprising thirty-seven separate communities in all. As will appear later, the matter of uniting more or less of these communities in closer municipal relations, possibly into a metropolitan water district, in some respects similar to that which supplies the Boston metropolitan district, is now being actively promoted, with practical certainty of ultimate success.

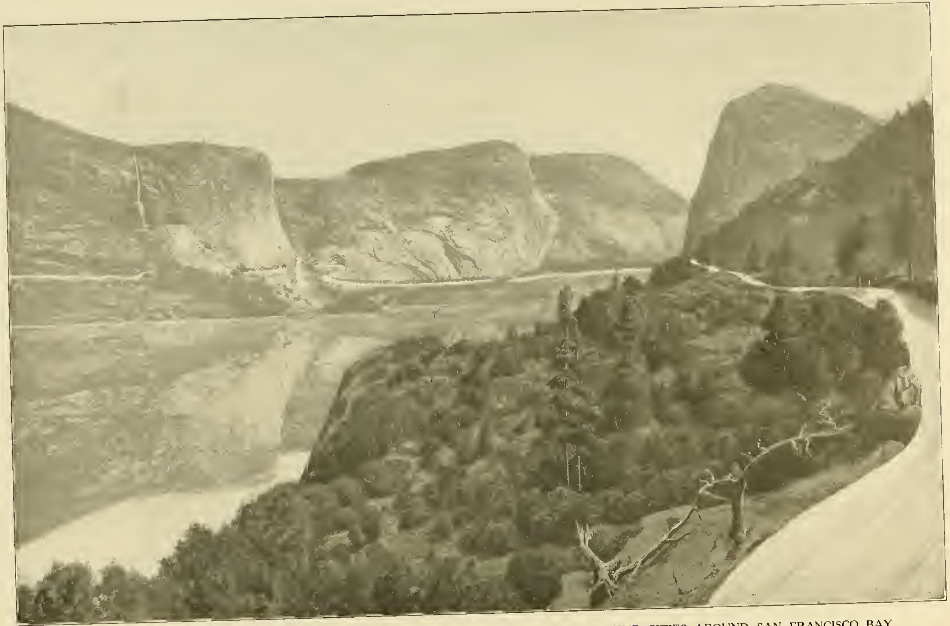
There is presented in Appendix No. 2 to this report a preliminary statement, prepared in the City Attorney's office, exhibiting in an incomplete manner the present status and the general trend of this movement.

THE PROPOSED HETCH HETCHY DEVELOPMENT.

The Hetch Hetchy Dam

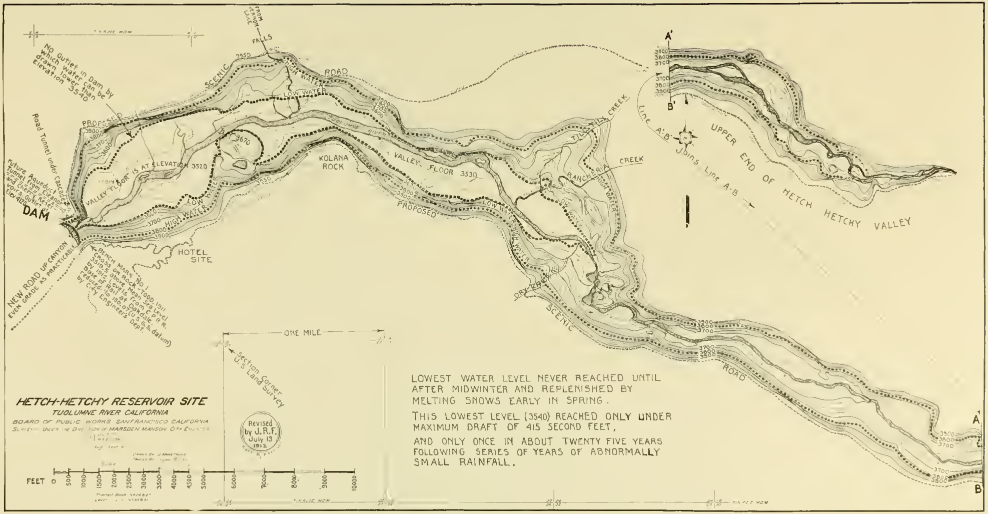
The City of San Francisco proposes:

(1) To build a masonry reservoir dam substantially as by plan attached, about 300 feet in height above the bed of the river at the dam site, in the narrow gorge at the outlet of the Hetch Hetchy Valley, by which the water can be raised about 270 feet above the nearly level floor of the valley; said



THE PROPOSED HETCH HETCHY RESERVOIR FOR THE FUTURE WATER SUPPLY OF ALL THE CITIES AROUND SAN FRANCISCO BAY.

View up the lake from near the proposed hotel site. Showing also the proposed scenic road around the lake. It is proposed to place the outlet pipes in the dam so high that the lake never could be wholly emptied.



HETCH-HETCHY RESERVOIR SITE

TUOLUMNE RIVER CALIFORNIA

BOARD OF PUBLIC WORKS SAN FRANCISCO CALIFORNIA

SURVEYED UNDER THE DIRECTION OF MARSDEN MANSON CITY ENGINEER

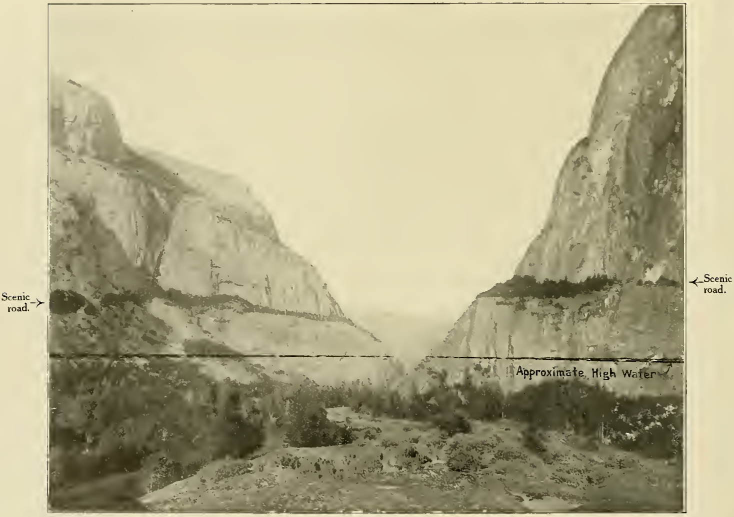
LOWEST WATER LEVEL NEVER REACHED UNTIL AFTER MIDWINTER AND REPLENISHED BY MELTING SNOWS EARLY IN SPRING.

THIS LOWEST LEVEL (3540) REACHED ONLY UNDER MAXIMUM DRAFT OF 415 SECOND FEET,

AND ONLY ONCE IN ABOUT TWENTY FIVE YEARS FOLLOWING SERIES OF YEARS OF ABNORMALLY SMALL RAINFALL.

Revised by J.R.F. July 13 1912

No Outlet in Dam by which water can be drawn lower than Elevation 3540
Road Tunnel under Cascade
Future Aqueduct Tunnel from Eleanor and Cherry Reservoirs Outlet at Elev 4120
DAM
NEW ROAD UP CANYON EVEN GRADE AS PRACTICABLE
BENCH MARK No 1 CROSS ON ROCK - TODD 1911 3519.5 above Mean Sea Level by 1912 Levels from C P R R. Base of Rail at Oakdale reduced to 150.07 (U.S.G.S. datum) by City Engineer's Dept.
HOTEL SITE
PROPOSED
SCENIC
ROAD
FROM VERNON LAKE
FALLS
3550
HIGH WATER
LOW WATER
VALLEY FLOOR IS AT ELEVATION 3520
3670
KOLANA ROCK
TUOLUMNE RIVER
VALLEY FLOOR 3530
TILTILLA CREEK
RANCHERIA CREEK
DRY CREEK
3600
3700
3800
3900
A'
B'
A
B
Line A'B' Joins Line A-B
UPPER END OF HETCH HETCHY VALLEY
ONE MILE
Section Corner U.S Land Survey
FEET 0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
6000
7000
8000
9000
10000



UP THE HETCH HETCHY, SHOWING THE DEPTH TO BE FLOODED IN RELATION TO HEIGHT OF CLIFFS.

The proposed scenic road is to run along the curious broad bench covered with stunted trees shown 200 or 300 feet above the high water line.

dam to have its outlets at such height that the water upstream cannot possibly be drawn so low as to uncover the level floor of the valley, which will thus always be covered by a broad, long lake. The shores of the lake will be very steep and largely composed of bare ledges. The lowest draft of the lake will not occur until after midwinter, and it will be replenished by the melting snows early in the spring. Seldom will the lake be less than three-quarters full on October 1st, and it will never be drawn within 20 feet of the bottom, save in one of the greatest droughts of the century. A careful demonstration of these facts is presented later.

Nearly all of this broad, level valley floor is now and has long been owned in fee simple by the City of San Francisco. The title to much of the steep, rocky shores remains with the United States; also the site of the dam and a portion of the upper valley floor. The City desires to obtain title to the dam site and to an amount of ground adjacent thereto reasonably sufficient for its construction plant, its construction camp and sufficient also for the work of building, for future maintenance, and for sanitary supervision of the margins of the lake; and the city also desires to co-operate with the federal authorities in a reasonable and proper supervision of the valley for the purpose of preventing the defilement of its waters.

A Wagon Road to Hetch Hetchy

(2) The City proposes to build a first-class well-surfaced wagon road with frequent turnouts such that teams can pass and upon a gradiant nowhere exceeding 8 per cent and commonly much less, into the Hetch Hetchy Valley from the old Yosemite stage road near Smith's Station, a distance of 23 miles approximately; and to forever maintain the same in good order, open to the public save when obstructed by snow or by washouts during the winter months. The quality of roadbed to equal that of the State highways. The city also proposes to either improve existing roads, or build new roads so far as may be necessary for obtaining easy grades and good quality of roadbed, westerly from Smith's Station to a point near the crossing of the main Tuolumne River near Moffatt Bridge, Jacksonville, doing this work of improvement of line, grade and surface at the city's expense, but in co-operation with the State or county authorities.

The city or its agents may require to lay railroad rails upon about one-half of the width of said roadbed, for better transportation of cement and other heavy materials during the work of dam building and aqueduct construction, and rights are

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IN NORWAY—A ZIGZAG ROAD BETWEEN MOUNTAIN AND LAKE.

The city of San Francisco proposes to build a public highway, fully as good as this, into the Hetch Hetchy Valley. First, for the purpose of hauling in cement and supplies for the dam, and afterward for the pleasure of its citizens and their friends.

desired to erect poles or towers for operative telephone service, for electrical power transmission, for construction or transportation, or other purposes alongside of said road.

This enterprise of road building is proposed for two purposes: First, for providing economical transportation of building materials, workmen and supplies to the site of the various construction works; and secondly, for the use and pleasure of the citizens of California, by making this region more easily accessible.

The city desires the rights of way and ownership of ground sufficient for the construction of such a road and permission to take from lands of the United States lying near, under reasonable restriction, any gravel, stone or timber or other building material suitable and useful for its construction. The betterment of transportation for the federal service should be deemed proper compensation for such material taken for road building and for other parts of the construction.

Scenic Road in the Hetch Hetchy Valley

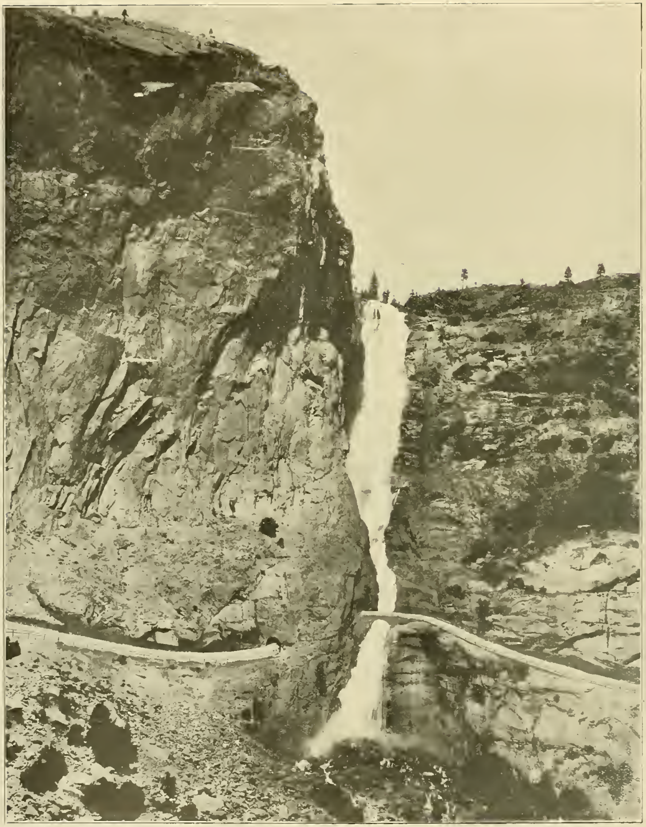
(3) The city proposes to build and maintain a scenic road along both shores of the proposed Hetch Hetchy lake. This road to have a surface nowhere less than fifteen feet in width, the grades seldom, if anywhere, exceeding 8 per cent, and with roadbed equal in permanence and surface to the State highways, and also proposes to construct one or more narrower and possibly steeper wagon roads branching from this circuit road into the Till Till Valley or other point of scenic interest; also to construct and maintain a good bridle path from near the dam to the top of Smith's Peak.

It is believed useful and profitable for the city to do this work in connection with the other work to be done in developing this source of municipal water supply, in order that the excellent character of this supply may be more widely appreciated, and also as a means for adding to the pleasure of its citizens, their California neighbors and their friends.

The city desires title to the ground beneath this scenic road and a strip outside of it sufficient for maintenance purposes, and also title to all ground between the said road and the lowest margin of the lake, or between it and the land which the city already owns, in order to efficiently protect the waters against defilement.

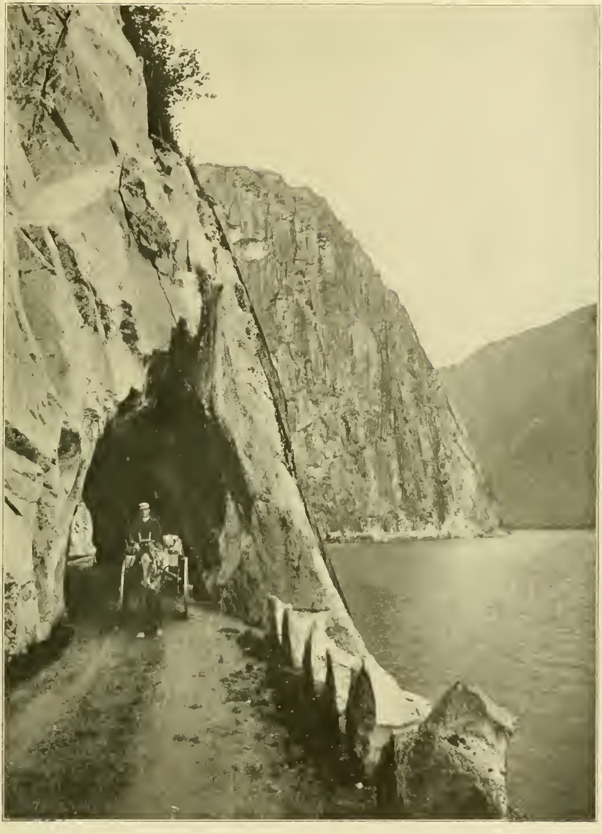
The Hetch Hetchy Aqueduct

(4) The city proposes to build an aqueduct from the Hetch Hetchy Valley to the city of San Francisco largely in the



WAPAMA FALLS, IN THE HETCH HETCHY, AND A PORTION OF THE PROPOSED SCENIC ROAD.

These lose much of their beauty as the summer advances, because of the lessened flow from Vernon Lake. This could be increased and controlled by a storage dam on its outlet, back in the mountains. This dam would also add to the city's water supply.



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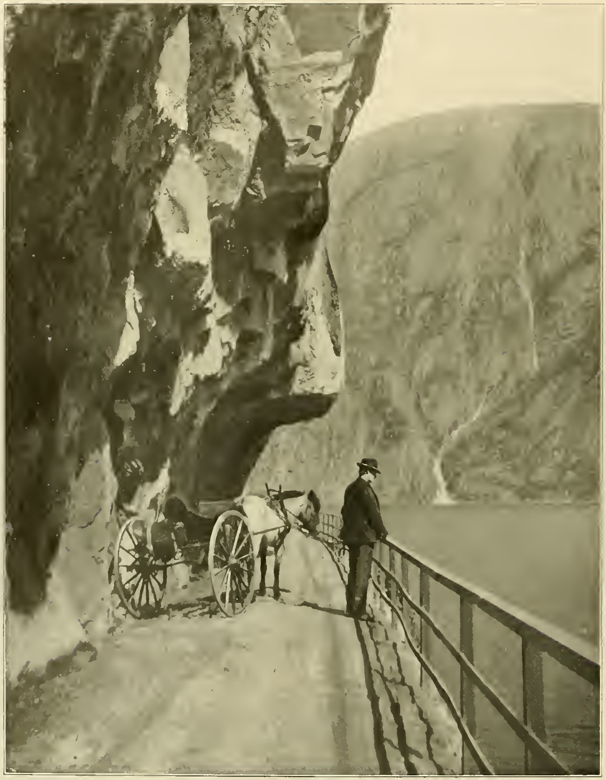
THE HETCH HETCHY SCENIC ROAD WOULD PRESENT A VIEW MUCH LIKE THIS (REVERSED) JUST WESTERLY FROM KOLANA ROCK.

The above shows a bit of the public highway along Oifjord Lake in Norway. It was while touring over certain of these Norwegian roads that the engineer developed his plan for a scenic road in the Hetch Hetchy.



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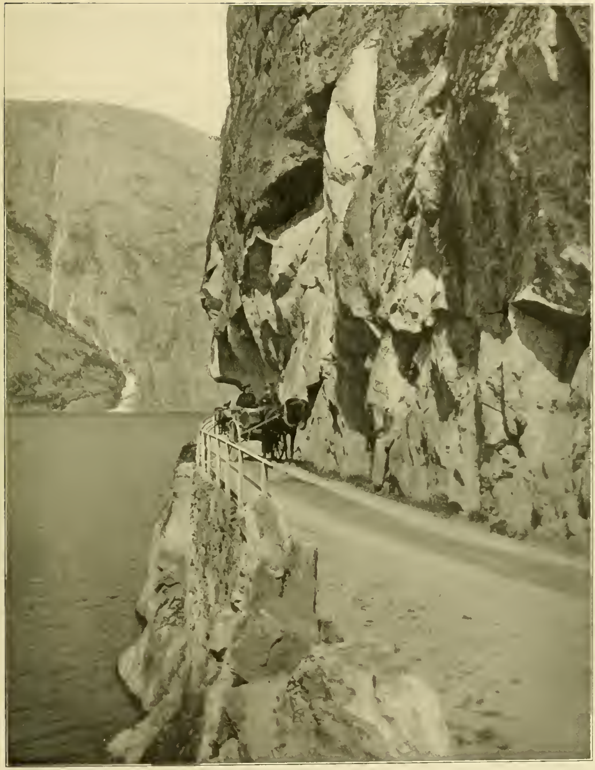
AN ARCADE ON THE PUBLIC ROAD ALONG LAKE OIFJORDS, NORWAY.

Several such roads have been built recently by the Norwegian government in order to invite tourists to points of scenic interest. The Hetch Hetchy scenic road is planned to contain two sections like this, beneath overhanging cliffs on opposite sides of the lake; also, another type with pillars of stone left to support the outer edge of the overhang, as on the Axenstrasse in Switzerland.



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PROPOSED TYPE OF CONSTRUCTION OF A PORTION OF THE HETCH HETCHY SCENIC ROAD, GOING FROM THE DAM TOWARD KOLANA ROCK.

form of a tunnel about ten feet in finished diameter, mostly deep beneath the surface of the ground, along the approximate route and at approximately the elevation shown in the accompanying plans and profiles, extending downstream from the proposed reservoir and dam to the easterly edge of the San Joaquin Valley. Thence continuing westward across this valley the projected aqueduct will be composed first of one steel pipe, 7 feet 6 inches net diameter, and ultimately of two steel pipes side by side, each about 45 miles in length. At the westerly side of the San Joaquin Valley the steel pipe portion is to end at a point about eight miles westerly from the confluence of the Stanislaus with the San Joaquin River. From this point the aqueduct line proceeds easterly, mostly in the form of a series of tunnels about 12 or 13 feet in diameter, to a point easterly from the village of Irvington, and about one mile northerly from Mission San Jose, on the hillside overlooking the southerly end of San Francisco Bay; at which point a terminal chamber and gatehouse would be built and branch aqueducts lead off as desired toward Oakland, San Jose, San Francisco and various other communities about the bay.

From this "Irvington gatehouse" the aqueduct would proceed westerly in the form of a steel pipe, submerged in the portion across the Dumbarton Narrows, near the head of San Francisco Bay (or could be carried on dry ground around the head of the bay), to a point of suitable elevation in San Mateo County, whence it could either discharge by gravity flow at an elevation of 320 feet above the mean sea level, through a new tunnel into the great storage reservoir of the Spring Valley Water Company at Crystal Springs, or could feed branch lines leading to the neighboring communities and into a main aqueduct line leading directly to the city of San Francisco. The valves and connections all along would be so arranged that the water could ultimately be delivered either directly from the Tuolumne River or ultimately from the Hetch Hetchy reservoir into the municipal distribution pipes without passing through any reservoir, or could be diverted into either of various reservoirs.

Capacity of Aqueduct

(5) The proposed aqueduct between the Hetch Hetchy and the Irvington gatehouse on the hillside overlooking San Francisco Bay is designed to deliver by force of gravity without pumping, a quantity somewhat in excess of 400 million gallons daily (equivalent to 620 cubic feet per second), and under extreme conditions possibly 500 million gallons daily. All of the tunnels will from the first be built to their full ultimate size and smoothly lined with concrete so as to have this capacity,

plus some reasonable excess for emergencies, and the steel pipe siphon at the Tuolumne crossing will be 10 feet net diameter, giving the same capacity as the tunnels.

When the second pipe across the San Joaquin Valley is added this quantity of 400 million gallons daily can be conveyed from Hetch Hetchy to the gatehouse, near Irvington, where it will be subdivided among the different communities contributing to its cost. During the early years, with only a single pipe across the San Joaquin Valley, the delivery of the aqueduct would be in excess of 200 million gallons daily—possibly 240 millions. The branch line of steel pipe to be taken across to supply the cities and valleys of the San Francisco Peninsula will have a capacity of about 100 million gallons per 24 hours.

All of the tunnels are to be smoothly lined with Portland cement concrete, and it is proposed to smoothly line with Portland cement mortar all of these steel pipes, in order to preserve the steel from rust and to maintain the carrying capacity undiminished, thus practically the aqueduct all the way from the Sierras to the street water-mains of San Francisco and Oakland will have an interior like a pipe of stone.

The communities to be immediately supplied require for domestic and municipal purposes less than one-half of the amount that the single pipe will bring, but since the surplus will flow without cost of pumping, it is proposed to bring all of the water that the one San Joaquin pipe will carry to the Irvington gatehouse and make the surplus available at a moderate meter rental, for irrigation, principally for intensive farming and truck gardens, almost anywhere around the agricultural lands bordering San Francisco Bay; very much as it is proposed to use the surplus capacity of the Los Angeles aqueduct; all of this use tending to the prosperity of those districts and tending to a cheapening of the food supply of Greater San Francisco, but with care to so frame the leases for this secondary water supply that it may forever remain available when needed for the higher purpose of domestic supply.

It will be briefly explained later in this report, as has been demonstrated in much detail in a separate report already filed relative to the water needs of the Turlock and Modesto Irrigation Districts, that all of this quantity up to the full 400 million gallons daily can be stored and diverted by the city without encroaching upon the priorities of these irrigated districts, and without taking waters that could be applied to other beneficial use for irrigation anywhere between the Stanislaus River on the north and the Merced River on the south.

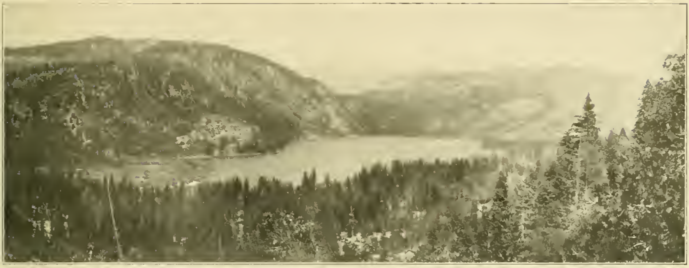
Also evidence will be presented to prove that in this semi-arid region where all pure running water is rapidly becoming appropriated, this quantity is none too great for the future "Greater San Francisco," and additional evidence to show that for the future safety and prosperity of these cities all waters now unappropriated on the Tuolumne River flowing into the city's three reservoir sites or upstream from the confluence of Cherry Creek and the Tuolumne, should be reserved for the domestic and municipal supply of these cities about San Francisco Bay and made inalienable from this, their highest possible use.

The Early Intake

(6) The portion of the tunnel about twelve miles in length next downstream from the Hetch Hetchy dam would be delayed in construction for some years, and meanwhile the city proposes to divert the water from the main Tuolumne River by means of a temporary dam across it at a point about one and a half miles upstream from the confluence of Cherry Creek, and the city desires to secure land titles, all rights of way and permits needful for entering upon and occupying any lands belonging to the United States under and adjacent to this "Early Intake," and for diverting at this point all water not called for under prior appropriations. Close beside this "Early Intake," at some future time, it is proposed to build Power House No. 2, and it is desired to now secure the necessary ground and rights of way appurtenant to this use, together with rights and permits for taking gravel, sand, timber or other building material useful for said purposes, from public lands lying near to the shafts or portals of said aqueduct or its connecting pipe lines.

Rights of Way

(7) The city also desires to secure rights of way and a fee title to a strip of land for all of the above described aqueduct and now particularly desires to obtain title from the United States to a strip of all the federal lands immediately adjacent to the proposed tunnel location or any reasonable modification thereof which may be found expedient upon fuller geological study, sufficient in width below ground for protection against mining operation, and sufficient in width above ground for the erection and maintenance of electrical transmission lines and for the protection of said transmission lines against windfall trees.

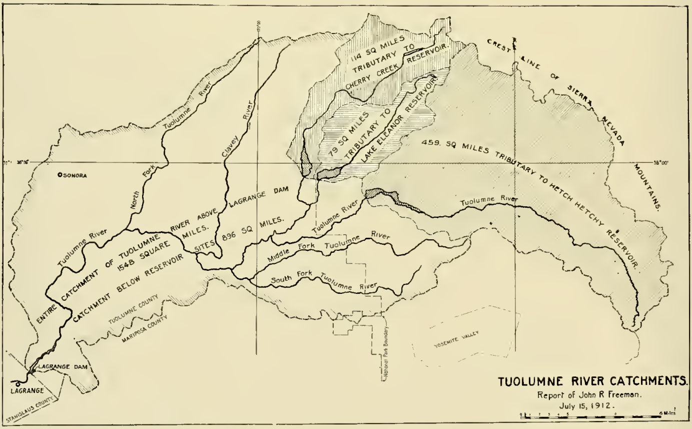


LAKE ELEANOR SITE FOR A FUTURE IMPOUNDING RESERVOIR, OWNED BY SAN FRANCISCO.

The outlet is so broad that a high masonry dam is very expensive. The watershed is so small (one-fifth that of Hetch Hetchy) that for 50 years to come it is proposed to build only a low earth dam and divert the water by a deep, steep tunnel into Hetch Hetchy.

IN THE TILL TILL VALLEY.

A branch from the scenic road is proposed into this valley, and should ultimately be extended around the contour of Mt. Gibson to the granite slopes around Vernon Lake.


114 SQ MILES TRIBUTARY TO CHERRY CREEK RESERVOIR.
79 SQ MILES TRIBUTARY TO LAKE ELEANOR RESERVOIR
459. SQ MILES TRIBUTARY TO HETCH HETCHY RESERVOIR.
CREST LINE OF SIERRA NEVADA MOUNTAINS.
ENTIRE CATCHMENT OF TUOLUMNE 1548 SQUARE MILES.
CATCHMENT BELOW RESERVOIR
RIVER ABOVE LAGRANGE DAM SITES 896 SQ MILES.
Tuolumne River
Clavey River
North Fork
Middle Fork Tuolumne River
South Fork Tuolumne River
SONORA
LAGRANGE DAM
LAGRANGE
TUOLUMNE COUNTY
MARIPOSA COUNTY
STANISLAUS COUNTY
YOSEMITE VALLEY
National Park Boundary
38°00'
TUOLUMNE RIVER CATCHMENTS.
Report of John R Freeman.
July 15, 1912.
Miles

Note the great extent to which the catchment of the Hetch Hetchy stretches along the crest line of the high Sierras, thereby securing an exceptional depth of snowfall in proportion to other Sierra catchment areas.

Note that the catchment area of Lake Eleanor does not extend back to the crest line. Its yield must correspondingly be smaller.

Eleanor-Cherry Aqueduct

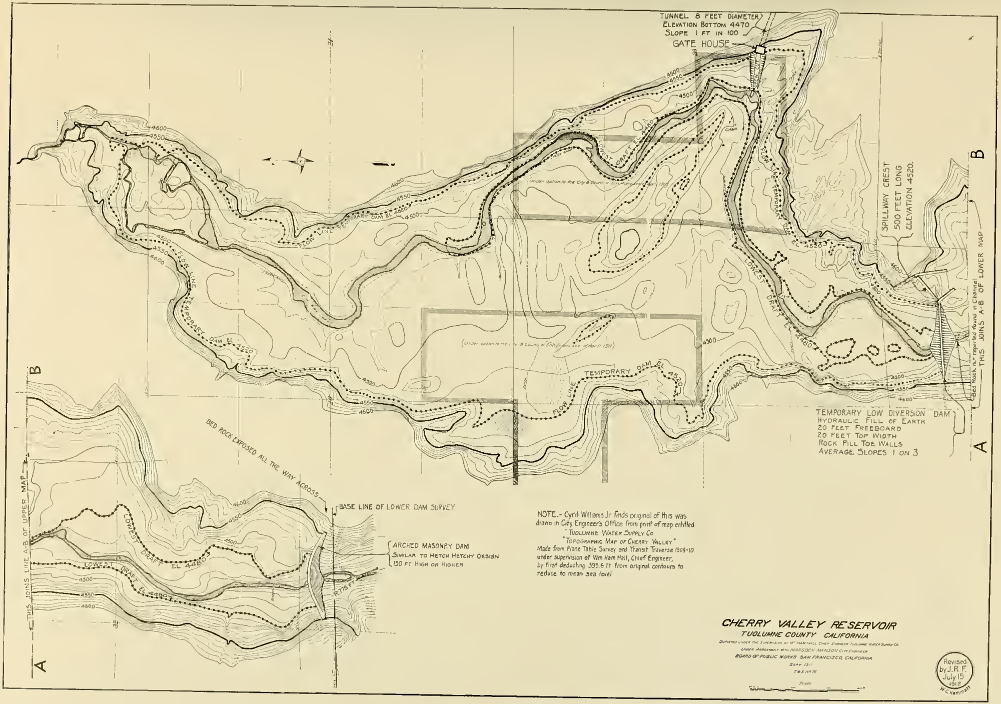
(8) Also the city proposes in the more or less distant future to build a tunnel about eight feet net diameter, deep underground, from a point near to and above the proposed Hetch Hetchy dam, over a northwesterly course to the reservoir site which the city owns on Cherry Creek, along the course and gradient shown in the accompanying plan, the said tunnel to pass directly beneath the Lake Eleanor reservoir site, also owned by the city, with appropriate gatehouses and intake shafts at Cherry and Eleanor for diverting their waters into the said eight-foot tunnel and thence into the Hetch Hetchy reservoir, for aid in replenishing it when the demand upon the city's source becomes large, and the city desires rights of way over and through the public lands sufficient for the above purpose, together with title to a strip of reasonable width, surrounding the said structures, with permits for taking building material from the public lands, adjacent to the said tunnel, under reasonable supervision by the U. S. Forest Service or other proper authority.

Eleanor and Cherry Temporary Dams

(9) The city proposes to build small, cheap dams at first for both the Eleanor and Cherry reservoirs, each at a site some distance upstream from the permanent damsite. These temporary dams, which may serve acceptably for 25 or 50 years, being mainly for diverting the waters into the steep tunnel to Hetch Hetchy already described, and to store for a few days the peaks of floods until the tunnel can take in the water which will be stored in Hetch Hetchy. Some storage will be retained in these reservoirs most of the year.

Eleanor and Cherry High Dams

(10) The city proposes at some future time, perhaps fifty or more years hence, when the demand for water becomes still greater, to replace these low temporary dams on Eleanor and Cherry Creek by high masonry dams of the most permanent and perfect character at the damsites already selected and surveyed at the outlets of Eleanor and Cherry creeks. There is an excellent granite foundation for a high dam at each of these sites, but at both the Eleanor and Cherry sites the great length of dam required for crossing the comparatively broad valley bottom and the great cost of transporting cement into this rough distant country and high altitude, across the Tuolumne gorge from the main highways, compels deferring the building of large dams here until the latest practicable date.



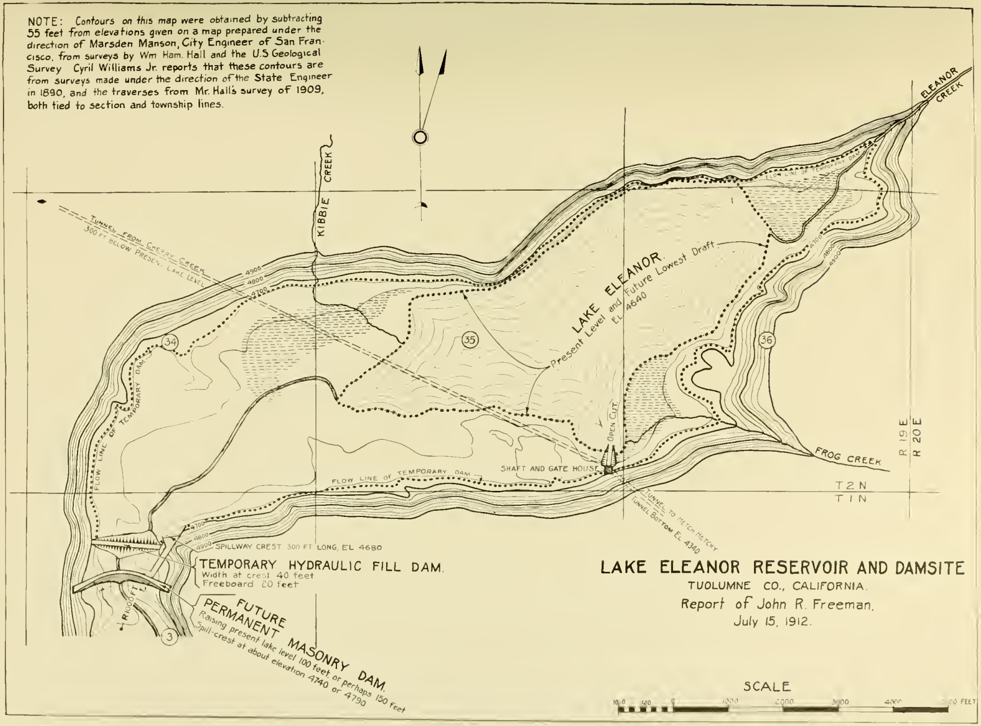
THIS JOINS LINE A-B OF UPPER MAP
A
B
TUNNEL 8 FEET DIAMETER
ELEVATION BOTTOM 4470
SLOPE 1 FT IN 100
GATE HOUSE
FLOW LINE TEMPORARY DAM EL 4520
LOWEST DRAFT EL 4480
4600
4550
4500
(Under option to the City & County of San Francisco April 1911)
SPILLWAY CREST
500 FEET LONG
ELEVATION 4520.
TEMPORARY LOW DIVERSION DAM
HYDRAULIC FILL OF EARTH
20 FEET FREEBOARD
20 FEET TOP WIDTH
ROCK FILL TOE WALLS
AVERAGE SLOPES 1 ON 3
Bed Rock not reported found in Channel
THIS JOINS A-B OF LOWER MAP
BED ROCK EXPOSED ALL THE WAY ACROSS
BASE LINE OF LOWER DAM SURVEY
ARCHED MASONRY DAM
SIMILAR TO HETCH HETCHY DESIGN
150 FT HIGH OR HIGHER
R.715 FT
31
32
Scale

NOTE.- Cyril Williams Jr finds original of this was drawn in City Engineer's Office from print of map entitled "TUOLUMNE WATER SUPPLY CO "TOPOGRAPHIC MAP OF CHERRY VALLEY" Made from Plane Table Survey and Transit Traverse 1909-10 under supervision of Wm Ham Hall, Chief Engineer, by first deducting 395.6 Ft from original contours to reduce to mean sea level

CHERRY VALLEY RESERVOIR
TUOLUMNE COUNTY CALIFORNIA

Surveyed under the supervision of Wm Ham Hall Chief Engineer Tuolumne Water Supply Co
Under Agreement with MARSDEN MANSON City Engineer
BOARD OF PUBLIC WORKS SAN FRANCISCO, CALIFORNIA
Sept 1911
[illegible]

Revised by J.R.F. July 15 1912
W C Hammatt



LAKE ELEANOR RESERVOIR AND DAMSITE

TUOLUMNE CO., CALIFORNIA.
Report of John R. Freeman,
July 15, 1912.

NOTE: *Contours on this map were obtained by subtracting 55 feet from elevations given on a map prepared under the direction of Marsden Manson, City Engineer of San Francisco, from surveys by Wm Ham. Hall and the U.S Geological Survey. Cyril Williams Jr. reports that these contours are from surveys made under the direction of the State Engineer in 1890, and the traverses from Mr. Hall's survey of 1909, both tied to section and township lines.*

ELEANOR CREEK
KIBBIE CREEK
FROG CREEK
LAKE ELEANOR.
Present Level and Future Lowest Draft.
EL 4640
FLOW LINE OF TEMPORARY DAM
TUNNEL FROM CHERRY CREEK
300 FT BELOW PRESEN. LAKE LEVEL
4900
4800
4700
34
35
36
3
OPEN CUT
SHAFT AND GATE HOUSE
TUNNEL TO HETCH HETCHY
TUNNEL BOTTOM EL 4340
SPILLWAY CREST 300 FT LONG, EL 4680
TEMPORARY HYDRAULIC FILL DAM.
Width at crest 40 feet
Freeboard 20 feet
FUTURE PERMANENT MASONRY DAM.
Raising present lake level 100 feet, or perhaps 150 feet
Spill-crest at about elevation 4740 or 4790
R 1000 FT
R 19 E
R 20 E
T 2 N
T 1 N
SCALE
1000
500
0
1000
2000
3000
4000
5000 FEET

The broad area of Lake Eleanor presents a very capacious storage for a given increase in height, but its catchment area is only about one-sixth part of that tributary to the Hetch Hetchy reservoir; moreover, this Eleanor catchment area is at an altitude where the average snowfall is smaller and is melted earlier in the spring.

At the Cherry reservoir also the catchment area is small, being only one-fourth of that tributary to the Hetch Hetchy. Moreover, the storage capacity in its reservoir is particularly small in relation to the quantity of masonry required in building a high and substantial gravity dam.

Although these unfavorable conditions are presented at the Cherry damsite, small storage for large cost, and at the Eleanor site, a small watershed, with relatively large cost for a masonry dam, the time will probably come in the distant future when dams of, say 150 feet in height, will be worth building at each of these two sites. A dam 150 feet in height at Lake Eleanor would store about 37 billion gallons of water, according to the City Engineer's surveys; and a dam 150 feet high at the Cherry site would store about 18 billion gallons, according to the report of Mr. Wm. Hammond Hall. At both sites the inaccessibility adds to the cost of any type of high dam proper for the location. The impracticability of planning an arched gravity dam of small radius for either of these two sites makes ample thickness of great importance under the severe winter conditions that may be found at this altitude.

Notwithstanding these disadvantages in cost and capacity, the city desires to preserve all its rights to the highest practicable dam at each site and to the storage of all of the tributary waters at each site which now remain unappropriated.

Other Reservoirs in Distant Future

(11) In the very distant future it may also become desirable to build supplementary reservoirs for the further storage and conservation of flood waters for the use of the city as a reserve against years of uncommonly low rainfall, these to be located upon Vernon Lake and other sites upstream therefrom, upstream from Rancheria Falls, and upstream from the Lake Eleanor and Cherry reservoirs. The city therefore desires that all permits for reservoir building on the public lands upstream from the Hetch Hetchy, Lake Eleanor and Cherry reservoir sites be reserved in favor of the municipalities of Greater San Francisco.

Eleanor and Cherry Wagon Roads

(12) The city proposes to construct in the near future a good wagon road both to the Eleanor and the Cherry damsite

from the Hetch Hetchy dam, and the city may find it expedient to build these roads long before the above described Cherry and Eleanor tunnels and dams are built. Therefore suitable permits for building these roads with suitable grants of public lands for them, are desired at the present time, together with rights to build electric lines for telephone or power along the said roads; and the city also desires grants of building material from adjacent public lands, as for the other roads above described.

It is not proposed to finish this Eleanor-Cherry wagon road to as great width or to so good a surface as the road into the Hetch Hetchy or that around the lake, until the time comes for important construction work at Eleanor or Cherry. There is no wagon road whatever into these regions at present; only rough mountain trails.

Power Development

(13) The city does not propose in the immediate future to build any plant for the development of hydro-electric power, but it plans to carefully conserve all reasonable opportunities for power development against the time when it may become expedient for the city to undertake such matters, and the aqueduct will be built with surge shafts, inclined tunnels and appurtenances suitable for the attachment of turbine penstocks, and with forebays for receiving water from the tailrace of future turbines, so that substantially the only added cost for power development will be that of the power house and its foundations, the hydraulic and electrical machinery and appurtenances, and the electrical transmission lines.

Power House No. 1 at Moccasin Creek

(14) There is only one power-drop in the aqueduct line first to be constructed. The power-house site for this is located very close beside the main highway at Moccasin Creek, six miles easterly from where the aqueduct line crosses the main Tuolumne River, and about 141 miles distant from the City Hall of San Francisco, along the aqueduct line, or 150 miles around the head of the bay.

The aqueduct capacity from the Early Intake down to the power house will be somewhat above 620 cubic feet per second, which is the equivalent of 400 million gallons daily.

The elevation of tailwater at this power house is planned to be 890 feet above mean sea level. The water level at the intake will be 2,315 feet, and the gross fall thus 1,425 feet.

Under working conditions, the head of the flowing water in the surge shaft at the top of the incline tunnel will be about 2,150 feet above sea level, giving a net working fall of approximately 1,250 feet when 620 second feet are flowing. With water wheels of ordinarily good design and efficiency this head and volume will produce 70,000 mechanical horsepower 24 hours per day, under conditions exceptional for efficiency and low cost of operation.

Power House No. 2 at Cherry Mouth

(15) Whenever the upstream twelve miles of aqueduct is completed between the Hetch Hetchy dam and the Early Intake, another power drop will become available immediately in the rear of the Early Intake, about a mile upstream from Cherry Creek, with the same 620 second feet of water already mentioned.

The gross fall here will be from the average surface of the lake at 3,750 to a tailrace level of 2,325, making a total of 1,425 feet.

But under working conditions and allowing for the hydraulic gradient, the power drop here when discharging this quantity will be from an average elevation of about 3,650 above sea level at the surge shaft, to an elevation of 2,325 in the tailrace, a net drop of 1,325 feet.

From 620 second feet on 1,325 feet head, with water wheels of ordinary efficiency there can be delivered 75,000 mechanical horsepower, 24 hours per day and 7 days in the week.

The city also proposes at some distant future time to construct a short, steep auxiliary tunnel and surge shaft at the downstream end of the Hetchy-Cherry-Eleanor tunnel by which the Cherry-Eleanor water, instead of falling into the Hetch Hetchy lake, can be diverted underground to a small hydro-electric power house, to be constructed near the base of the Hetch Hetchy dam, with an electrical transmission line leading off thence toward the city, along the new roadway already described.

Power House No. 3 at Cherry-Eleanor Tunnel

(16) From the Cherry-Eleanor conduit with the low dams there could not be so much power developed in the early years as after the regulation of their flow by the future high dams, because in the earlier years their spring floods will be discharged with a rush, thru the steeply inclined tunnel into Hetch Hetchy. Still, it would be worth saving, by a plant designed more particularly for future conditions. This power

would have a special value for supplementing the other power at times of peak loads without sacrifice of water, by discharging into Hetch Hetchy Lake instead of into the aqueduct. At some distant future day this Cherry and Eleanor power will become valuable. Its ultimate amount may be reckoned as roughly equivalent to an average flow of 175 second feet, altho its rate of delivery would be irregular and chiefly useful at peaks in supplementing the other power plants.

From this quantity of water under a power drop from Eleanor, or Cherry, to Hetch Hetchy averaging about 800 feet net fall, there could be generated an average of 12,500 horsepower of mechanical power. In the early years with the small storage and the rapid drawing thru the tunnel for replenishing Hetch Hetchy, less power could be conserved.

The Total Power

(17) Adding up the power at these three sites we would have ultimately a total of 157,500 mechanical horsepower available 24 hours per day and 365 days in the year; supplying possibly 200,000 horsepower at peaks, under ordinary practical conditions.

Whenever the proper time comes, there can be constructed in the valley of Moccasin Creek a small equalizing reservoir, suitable to permit some variable rate of power delivery without wasting water, but this would have to be worked out with care to avoid exposure of the water to contamination and is all so remote that it need not be considered now. Power development should be subordinate to domestic water supply at every point, and I have designed the works with this as a fundamental idea.

At all three sites the cost of power house and that of the hydro-electrical machinery will be exceptionally small and the flow of water uncommonly constant and dependable. On the other hand, the transmission line, altho laid mostly over the aqueduct rights of way, would be 150 miles long to San Francisco and 135 miles to Oakland, and cost a large amount of money.

Today, with cheap oil fuel and with three large hydro-electric enterprises bringing electric current to the city and competing actively for business under the oversight of a public service commission, no occasion appears for the municipality to go into the power business. Moreover, it is said that its charter does not permit the city to engage in this commercially.

Value of the Power Asset

(18) The time will surely come when this power privilege

will be a most valuable asset of the Tuolumne water supply system.

There will doubtless be a limit to the era of oil at present prices and year by year new electro-chemical manufacturing processes are being discovered, in some of which an abundant supply of electrical energy would add to the prosperity of Greater San Francisco. As the city grows and increases its municipal activities, its own demands for electric current, for lighting and for power may become large enough to warrant the large cost of a transmission line 150 miles long.

Another possibility is that in course of time some power company would at its own expense build the upper twelve miles of aqueduct under the city's specifications and oversight, in return for a concession for a term of years to develop this power, and to turn the power plant over to the city without cost at the end of the term.

It is plain that this valuable asset of about 200,000 mechanical horsepower and presenting with the first installation of the aqueduct and pipes 70,000 horsepower of constant 24-hour mechanical power, an amount greater than is developed today at any one hydraulic power house outside of Niagara, ready for quick and cheap development, should be reckoned into the balance sheet when comparing the Tuolumne source with others that present no such potentiality.

Sanitary Control

(19) As to sanitary restrictions, the city proposes nothing beyond those now acceptable the world over, as properly safeguarding the great storage reservoirs for municipal domestic supply, such for example, as those today in force around the impounding reservoirs of Boston, New York, and many other cities which maintain most scrupulous health bureaus and which do not filter their water.

As a result of repeated exhaustive scientific investigations of the foremost health authorities in the United States, Germany and England, it has been proved beyond the shadow of a doubt that long storage in reservoirs is one of the greatest of sanitary safeguards to a drinking water supply, and that it is standing water rather than running water which purifies itself. Stated in plain, commonsense terms, the reason is, that in the course of a month or two at the most, any pathogenic germs die under this unfavorable environment.

In the present case, with a cold mountain water coming chiefly from melting snows, running over granite steeps, in a region so sterile and so cold and at such an altitude that man is absent half the year and never present in a number statistically large when expressed in the ordinary sanitary terms of number of inhabitants per square mile; the possible dangers and the sanitary restrictions necessary will both be less than in the case of distributing reservoirs within populous communities like those of Boston and New York.

The sanitary control and tendency to exclusion of the people from the region upstream from the Hetch Hetchy might properly be much less severe than for the ordinary impounding reservoir, instead of leading to such absurd restrictions as some who in the past have opposed the use of this valley for a reservoir site have, in their excited state of mind, claimed would be enforced.

Any statement that the use of the Hetch Hetchy for domestic water supply storage would probably cause the exclusion of tourists and campers from the watershed tributary thereto is utterly without foundation and those who suggest it set up a fanciful standard of their own for San Francisco, far more rigorous than is found needful by sanitary science or called for by experience in the study of water-borne disease, and far more rigorous than is in force for the drinking-water supplies of Boston, New York, Los Angeles, Seattle, Portland, Oregon, or Portland, Maine, Glasgow, Manchester, Birmingham, or so far as is now known, any city in the world either with or without filtration works. The public wagon road to Half Moon Bay crosses the Crystal Springs reservoir of the present San Francisco supply on the division dam.

Water Measurement

(20) For the measurement of the inflow and outflow from the Hetch Hetchy, Eleanor and Cherry reservoirs it may become desirable in case of any disagreement or dispute with the irrigation companies as to release of their priorities, to construct substantial masonry gauging weirs across the principal streams entering the reservoir; and the city desires to secure proper sites for building these gauging weirs. The city proposes as a part of its dam and gatehouse construction at each reservoir to install simple and efficient water-gauging apparatus and to keep a proper record of the flow, which shall at all times be available to the Hydrographic Service of the U. S. Geological Survey, to the Irrigation Districts and to the public in general, and to make other meteorological studies concerning the yield of these catchment areas which promise to be of much utility in the better planning for the conservation of the waters of the State.

Irrigation Use

(21) It has been already stated that it is proposed to utilize the surplus carrying capacity of the aqueduct in early years for supplying water for agricultural purposes at all convenient points between San Francisco Bay and the surrounding hills. It is possible, altho not particularly promising, that the surplus carrying capacity of the tunnels between the San Joaquin Valley and the intake could be made useful for the next half century in supplying water for the irrigation of fruit orchards, etc., in the foot hills near the aqueduct line southeasterly from Oakdale at any altitude below 800 or 850 feet. It would cost practically nothing to bring this water to the valley's edge through the full-sized tunnels, and it might better be used here than to flow unusued down the river channel to the sea. One difficulty in this use, although the trouble is a long ways off, is that the time would come when it would have to be taken away and the land revert to present conditions, and great care would need to be exercised that no servitude was established upon the water which would prevent it being taken to the city after due notice.

Sanitary Rules

(22) The statement of the sanitary restrictions proposed by the City of San Francisco for the protection of the Hetch Hetchy and Lake Eleanor reservoirs, for which the Secretary of the Interior asks, may be covered by the statement that these would consist chiefly in a few commonsense regulations such as:

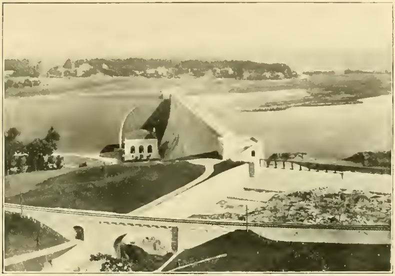
(a) The rules now in force in the Yosemite Valley against littering the ground.

(b) The forbidding of bathing in the reservoir or the river upstream therefrom. This water, from melting snows, is commonly so cold that a plunge would present small attraction to the average camper.

(c) A decent care to avoid depositing camp wastes, rubbish, excrement, or other defiling material, solid or liquid, in or near to the reservoir, or near to water flowing into the reservoir.

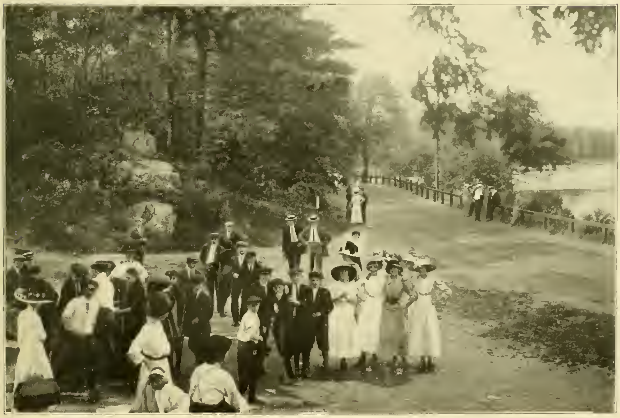
(d) For whatever hotels or cottages are built within the Hetch Hetchy Valley, simple efficient sewerage appliances should be installed,—for example, septic tanks, incinerators and the filtration of effluents thru coarse sand.

(e) These regulations should be formulated and enforced by the Federal authorities in charge of the Yosemite, the same as those now enforced for other parts of the park, but revised for this valley in co-operation with the water officials and the health officers of the city.



AT THE WACHUSETT DAM, CLINTON, MASS.

This controls Boston's main impounding reservoir. Note the roads within the catchment area. There are several small mill villages and a permanent population of about 5,000 upstream from this reservoir.



A PICNIC GROUP ON THE PARK ROAD AROUND BOSTON'S MIDDLESEX FELLS RESERVOIR.

There would be far less reason for excluding the campers and tourists from that part of the National Park area upstream from the Hetch Hetchy Reservoir than for excluding the thousands of permanent dwellers and picnickers from these Boston watersheds, and there is not the slightest probability that the public will ever be excluded, or restricted from reasonable enjoyment, in either case. (Some of those who have most violently protested against San Francisco's use of the bottom of the Hetch Hetchy Valley for reservoir purposes in the fear that it will exclude tourists and campers from all this part of the Sierra Nevada Mountains, live in Boston and New York, hence these illustrations.)

Fishing and Camping

(22a) Fishing along the tributary streams or in the upstream part of these reservoirs need not be prevented, and camping at any point more than a mile upstream from the head of the reservoir can do no possible harm.

The ordinary proprieties which any decent man would regard, knowing that these waters were to be used for domestic supply, are all sufficient and all necessary supervision could be readily enforced by a single park policeman, on duty one-third of the year, and by the posting of notices at intervals along the shore in the frequented places, just as is done on the shores of the Spot Pond reservoir of Boston and around the margins of Boston's Chesnut Hill reservoir, shown in accompanying photographs.

While reaching a decision as to what regulations would be proper and reasonable for the Hetch Hetchy, it is instructive to study various notable precedents.

The Example of the Boston Metropolitan Impounding Reservoir

(23) The plans for the recent extension of the Boston supply were worked out under the supervision of the Massachusetts State Board of Health with the aid of as competent scientific knowledge regarding water-borne diseases as was then available in the world. The supply is obtained by impounding the water of the Nashua River, which flows over a catchment of about 119 square miles of hilly farming-country, which contains several small factory villages, and a permanent population of about five thousand people, or 45 to the square mile. The runoff is collected and stored in the Wachusett Reservoir. The mean annual temperature of this reservoir is much more favorable to organic life and the water contains a much larger food supply for micro-organisms than at the Hetch Hetchy, Lake Eleanor or Cherry Creek reservoirs.

Excellent highways have been built by the Water Board around the reservoir margins, commonly kept several hundred feet distant from its shores, and one of the sanitary protections against pollution around this marginal strip of land is the posting of a few notices here and there to remind visitors that this water is used for domestic supply. The public is freely admitted to these lands and portions of the margins are being reforested. Long detention of the water running off the catchment, in this great impounding reservoir, is the chief sanitary safeguard.

A SUNDAY AFTERNOON STROLL ALONG THE SHORE OF BOSTON'S MAIN DISTRIBUTING RESERVOIR IN THE MIDDLESEX FELLS.

This park road has become so popular that the members of the Water Board now regret that a broader margin for low shrubbery and greensward was not provided between the road and the lake, in order to keep the road dust from the lake. The above view is near the southerly end of reservoir.

The risk of typhoid or other water-borne germs being introduced to a public water supply by the admission of the public to temporary or permanent occupancy of the catchment is a very different matter in the case of a large impounding reservoir from that of a public water supply taken directly from a running stream. The germs do not propagate in the stored water but lose their virulence and become destroyed within a brief time.

The Example of the Boston Distributing Reservoirs

(24) Within the Boston Metropolitan District are several large distributing reservoirs, built as safeguards against interruption and for equalizing the action of the pumps.

The Middlesex Fells Reservoir is the most notable of these. It contains about 275 acres, and just outside of its drainage area are populous communities. It was formed by raising the level of Spot Pond and improving its margins by cutting off some of the swampy flowage and placing clean gravel along its shores. This reservoir lies almost in the center of the most important of the Metropolitan Parks and the Park Board have improved old roads and built others so that the lake is encircled by one of the most beautiful park roads of the Boston District and one which is frequented by thousands of men, women and children on every pleasant summer holiday.

For protection against defilement, reliance is placed upon a mild supervision by the park police and a few water-works employes, and upon neat sign boards placed at intervals along the shores, calling attention to the fact that these waters are used for domestic supply. The detention of the water in the reservoir and the natural processes of sedimentation and exposure to sunlight are relied upon to prevent injurious effects from any chance pollution.

(25) The Chestnut Hill reservoir of the Boston system, lies within one of the most beautiful residential suburbs of Boston, only five and one-half miles from the City Hall and alongside of one of the most popular boulevards and pleasure drives. Much attention has been given by the Water Board to landscape architecture of the marginal lands. The public is freely admitted to the roadways and footpaths, and on pleasant holidays passes over them literally by the thousands. For protection against pollution reliance is placed chiefly upon sign boards calling attention to the use of the water.

Detention of the water in a large reservoir, here, as at the other reservoirs, is the chief sanitary safeguard relied upon by the health authorities and water-works officials of Boston, and a careful analysis of the health statistics is said to prove that the present conditions are not unsafe.

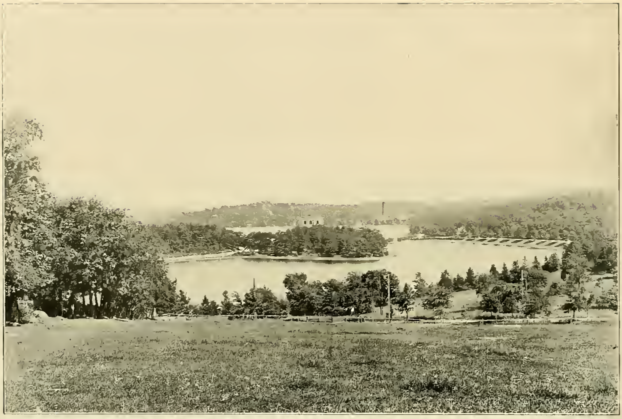
(26) The Mystic Lake reservoir. This has not been drawn upon for domestic supply in 12 or 15 years past, but for many years was the immediate source of supply to certain large sections of the Boston suburbs, and gave convincing proof of the efficiency of long storage in a reservoir as a sanitary safe-

↑
Over the arrow is seen one of the signboards warning against pollution.

ON THE ROAD AROUND BOSTON'S FELLS RESERVOIR.

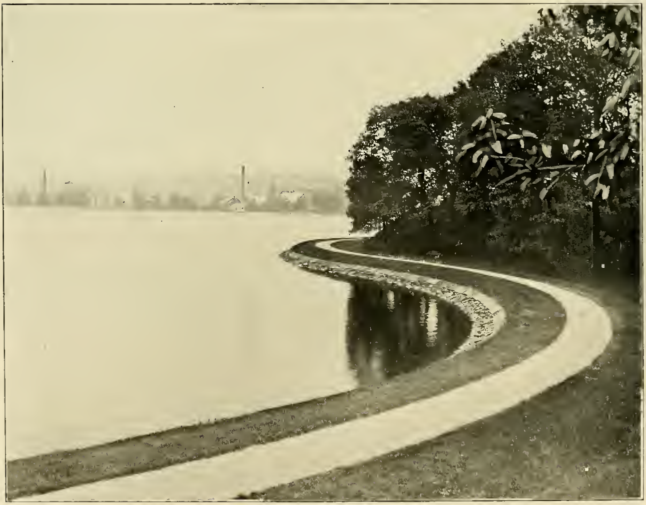
This reservoir lies in the center of the chief park or "Reservation" of the Boston Metropolitan Park System, an elevated rocky, forest-covered area of about three square miles only five and one-half miles from the dome of the Massachusetts State House. The two impounding and storage reservoirs for the town of Winchester also lie within this reservation; also the Metropolitan high service reservoir. The water from all of these is used for domestic supply without filtration. These water supply reservoirs are the chief features in giving to this park its peculiar charm.

The writer lived near the border of this reservation for ten years, and as member of the Winchester Water Board, and later of the Metropolitan Water Board, had occasion to frequently observe and study the conditions affecting the possibility of pollution of these water supplies.



BOSTON'S CHESTNUT HILL RESERVOIR, WITH PARKED BORDERS, IN MIDST OF A POPULOUS SUBURBAN DISTRICT.

Pumping station in the distance.



AN INVITING FOOT PATH BORDERING BOSTON'S CHESTNUT HILL RESERVOIR.

The pumping stations are seen across the water.

MARGIN OF BOSTON'S CHESTNUT HILL RESERVOIR ON A SUNDAY AFTERNOON.
Note the signboard cautioning against pollution.

BOSTON'S CHESTNUT HILL RESERVOIR AND A PLEASURE ROAD NEAR IT.

BOSTON'S SUDBURY RESERVOIR (IMPOUNDING AND STORAGE).

Margin uncovered as the water is lowered. Note the highway at the left. The Burnet residence in the distance.

THE NEW ROAD AROUND CROTON DAM AND LAKE, BUILT BY THE NEW YORK AQUEDUCT BOARD.

guard. The writer had occasion during some years to be well informed concerning the pollution of the stream that entered the Mystic Reservoir from populous villages and factories on its shores, from street wash and many objectionable features such as old privies close to its banks. Yet no larger percentage of typhoid or other diseases from water-borne germs, was noticed in the communities which drank this water than elsewhere.

The conditions were so remarkable that the writer discussed them repeatedly with eminent biologists and sanitarians.

This water would have been positively dangerous if taken direct from the running stream that entered the reservoir, but after its detention, sedimentation and sunning in the reservoir for six months more or less, the reservoir being large and shallow in proportion to the flow, the health statisticians found no increase in disease resulted from its use, when comparison was made with the parts of the city having water from a far better source.

HIGHWAYS AND PLEASURE DRIVES AROUND CROTON LAKE, AT PRESENT NEW YORK'S CHIEF STORAGE RESERVOIR.

Hundreds of automobiles tour around this artificial lake each pleasant Sunday afternoon in summer. The site of the old Croton dam, now submerged, is near the center of the picture. There is a resident population of about 23,000 and 78 miles of railroad within this catchment area.

Example of the New York Impounding Reservoirs

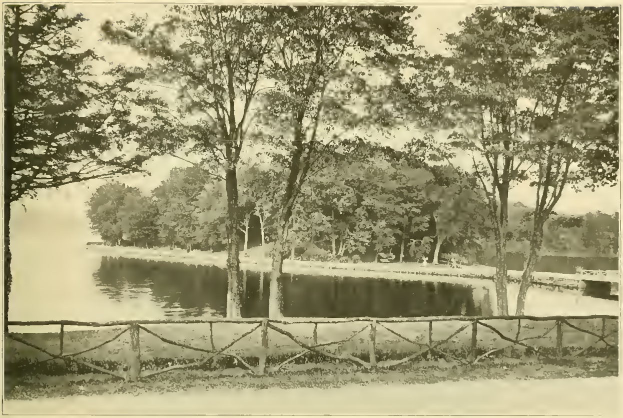
(27) There are many colonies of summer cottages and also many year-round dwellings and stores, located in the mountain valleys tributary to the great Ashokan storage reservoir of the new supply from the Catskill Mountain region, now under construction for Greater New York, and a railroad and a highway much patronized by summer tourist travel and by week-end visitors, runs for miles adjacent to the principal tributary stream.

Several small sewerage treatment systems are to be built at the villages and summer hotels for the protection of this water supply, but all of the road wash and ordinary surface drainage of the countryside will find its way over the surface of the ground to the reservoir. Yet no danger whatever of sanitary disturbance from this is feared. The long detention of the water in the reservoir is relied upon to afford sanitary protection to those who drink it. As a part of the project a place has been made in the aqueduct line near the city for filters, but it is not expected to install these on the Catskill supply for many years to come.

A PUBLIC ROAD ALONG THE MARGIN OF THE TITICUS IMPOUNDING RESERVOIR, NEW YORK WATER SUPPLY.

A NEW PUBLIC HIGHWAY ALONG THE ASHOKAN RESERVOIR IN THE CATSKILL MOUNTAINS.

Recently built by the New York Board of Water Supply.



ROADS OPEN TO THE PUBLIC AROUND LAKE MAHOPAC, ONE OF NEW YORK CITY'S IMPOUNDING RESERVOIRS.

A PUBLIC ROAD BUILT BY NEW YORK BOARD OF WATER SUPPLY AROUND KENSICO RESERVOIR, NOW UNDER CONSTRUCTION.

The reservoir site, not yet filled, is at the left of the picture.

LAKE THIRLMERE.

The new source of water supply for Manchester, England. Used without filtration.

Some Foreign Examples

(28) Lake Thirlmere, England, presents a notable example. Here about twenty-five years ago, in order to furnish a new water supply for the City of Manchester, the marginal lands around the lake were purchased by the city, a dam was built at its outlet, raising the water some fifty feet, more or less, and an aqueduct nearly a hundred miles in length was built to that city.

There was a great popular outcry in newspapers and elsewhere, in which bishops, baronets, actors and literary artists joined with great fervor, about the desecration of this beautiful lake for such an utilitarian purpose, merely, as it was said, to save the city the extra cost involved in going to some less beautiful spot.

But in the course of their works the Water Board completed a beautiful macadam road encircling the lake, and giving along its westerly shore many beautiful views of Mt. Helvellyn, from points to which there had previously been no good road.

The roads about this reservoir have come to be one of the most popular holiday routes in England, and are much traveled by coaching parties, automobiles and groups of cyclers. It is estimated that during the year eight or ten thousand persons travel these roads, which pass within a few hundred yards of the lake and wholly within its catchment area. Some of the old farmhouses near the margin of the lake are still occupied and serve dairy products and light refreshments to cyclers and pedestrians. I have had the pleasure of passing over this road since I began my studies of the Hetch Hetchy problem. I stopped at various of the farmhouses to observe conditions and conferred afterwards with the water works authorities and was told that it was found a very simple matter to preserve a decent public spirit against defiling the water, and that it was now widely recognized by the public that the road building and other improvements of the water works had been a distinct gain to the attractiveness of the region.

ON THE PUBLIC HIGHWAY IN THE CATCHMENT OF LAKE THIRLMERE.

All of these slopes are tributary to the catchment of the lake. It is said that 8,000 to 10,000 tourists pass over these roads each year. In the group of buildings at center there is a little inn.

THE SLOPES OF MOUNT HELVELLYN.

Lake Thirlmere seen across the lake from the water works road.

(29) Reservoirs for the water supply of the city of Birmingham, England, have recently been built in Central Wales on the Elan River, and an aqueduct some seventy miles in length built to the city. On inspecting these works, I found that, as a part of their project, the water supply authorities had built beautiful roadways encircling the reservoirs, which were open to the public travel and frequented by automobiles and cyclers, and that the reservoirs and their dams were regarded as having added materially to the attractions of this mountainous region. Their Craig Gooch dam, which I was fortunate in finding with the quantity of overflow shown in the photograph, is an object of beauty worth traveling far to see. Here, again, detention in the reservoir is regarded as a sufficient sanitary safeguard. The waters are not filtered, altho they pass thru a straining process for preventing organic matter from entering the pipes.

LOCH KATRINE.

Source of Glasgow's water supply. Ben Venue in the distance. A source that is found satisfactory without filtration.

(30) The water supply of Glasgow, Scotland, comes from Loch Katrine, thru an aqueduct some thirty or more miles in length and is used without filtration. Within the catchment area runs one of the most popular roads for coaching parties and tourists, who transfer from coach to the steamer at an inn near the borders of the lake. It is stated that between five and ten thousand tourists cross the lake and pass over the roads within its watershed each year. I counted nearly one hundred on the day that I made the trip. Inquiry was made as to

THE STRONACHLACHER HOTEL, ON THE SHORE OF LAKE KATRINE.

Where many thousands of tourists change from coach to steamer each summer.

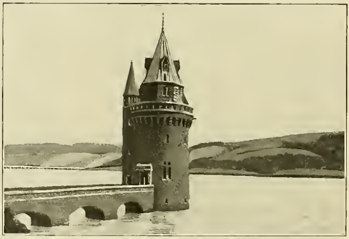
Copyright by Underwood & Underwood, New York.

TOURIST STEAMBOAT CROSSING LOCH KATRINE, SOURCE OF GLASGOW'S WATER SUPPLY.

Note the road along the margin; also the small motor boat near the shore.

ROAD AND COTTAGES ON MARGIN OF LOCH KATRINE.

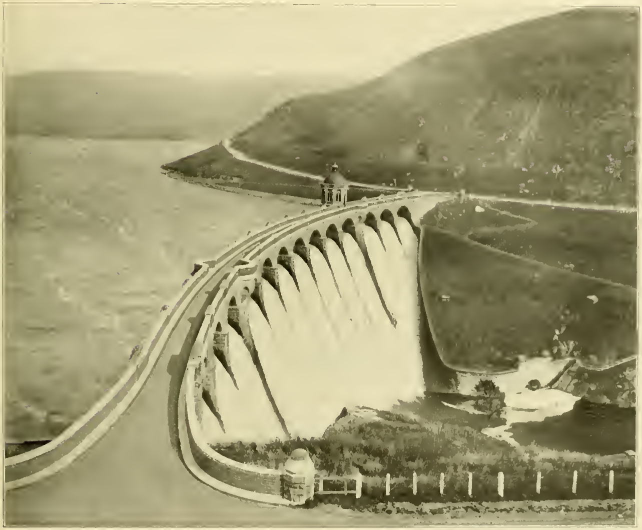
COACHING PARTY ARRIVING NEAR STEAMBOAT WHARF, LAKE KATRINE.



INTAKE TOWER OF THE VYRNWY RESERVOIR IN THE MOUNTAINS OF NORTH WALES, LIVERPOOL'S SUPPLY.

The reservoir is surrounded by an excellent road.

AN ILLUSTRATION THAT DAMS AND RESERVOIRS FOR PUBLIC WATER SUPPLY MAY ADD TO THE BEAUTY OF A LANDSCAPE



THE BEAUTIFUL CRAIG GÔCH DAM, ELAN RIVER, WALES.

New works for the water supply of Birmingham, England. Note the inviting roads, built chiefly for the pleasure of the public.

the sanitary precautions, and so far as I could learn or observe these were simply such as decency and commonsense would dictate. On the steamer care was taken to prevent throwing any defiling material into the water, and ordinary care was taken to prevent house waste from running directly into the lake.

There is almost no end to similar examples that may be cited among communities that are highly intelligent and scrupulously careful about the sanitary condition of their water supply, in order to prove the utter absurdity of the statement industriously circulated that the use of the Hetch Hetchy as an impounding reservoir for the water supply of San Francisco would exclude from its watershed tourists and campers, now or in the future, or lessen the pleasure to be found within the limits of the Yosemite reservation.

Hazen Report

Attention is called to the following report on the quality of the Tuolumne water and conditions growing out of a joint use of the catchment area for water supply and park purposes, prepared last year by the eminent chemist and water supply expert, Mr. Allen Hazen, after a personal visit to the Hetch Hetchy, Lake Eleanor and the Cherry Creek reservoir sites.

REPORT BY ALLEN HAZEN, CONSULTING ENGINEER, UPON QUALITY OF THE TUOLUMNE WATER AND CONDITIONS GROWING OUT OF A JOINT USE OF THE CATCHMENT AREA FOR WATER SUPPLY AND PARK PURPOSES.

Report of Mr. Allen Hazen's Investigation.

(31) The catchment area of the Tuolumne River above the Hetch Hetchy Valley and of Lake Eleanor is in part covered by heavy natural forests and in part composed of great granite areas almost entirely without soil and vegetation. The rock is all granitic, and of the most insoluble character, and experience shows that waters derived from such formations are remarkably free from dissolved mineral impurities.

Not many analyses have been made of the Tuolumne water above the points where less pure drainage is received from the foothills, but the few that have been made indicate that the water will be of the greatest purity.

The catchment areas are practically uninhabitable at the present time. Those parts not owned by the United States are practically all owned by the City of San Francisco. The only populations upon them are:

1. The men employed by the City of San Francisco in gauging streams and doing other necessary work.
2. The summer camps of the U. S. troops and other men doing police and forest duty in the park and forest reserve.
3. Occasional temporary camps or visitors.

It would be difficult to conceive of a more perfect gathering ground, or one better adapted to produce water of greatest purity. The water will be almost ideally safe.

Storage

To utilize this source of water supply it is proposed to build a large reservoir in the Hetch Hetchy Valley, and another by raising Lake Eleanor, to hold back the flood flows and make them available throughout the dry portions of the year. The bulk of the water utilized will be from such flood flows, and represents water not now utilized.

The storage of water in large reservoirs for considerable periods tends to eliminate, and actually does eliminate, nearly all of the effects of pollution upon the water running into the reservoir. The catchment areas of the Croton, Sudbury and Wachusett reservoirs have large permanent populations upon them, but the storage of the waters makes them safe from a hygienic standpoint, even when used without filtration.

The following is a tabular statement of a few Eastern catchment areas, with their populations computed from the census of 1910, and the miles of railroad upon each:

Place.	Catchment Area.	Area Sq. Miles.	Population 1910 Census.	Per Sq. Mile.	Miles of Railroad on Area.
New York	Croton	360.44	23,019	64	78.0
New York	Esopus	255.00	8,694	34	30.5
Boston	Wachusett	118.90	5,282	45	33.5
Boston	Sudbury	75.20	22,111	294	27.5
Boston	Cochituate	18.73	4.877	260	14.1
Rochester	Hemlock Lake	43.00	1,401	33	7.0
Syracuse	Skaneateles Lake	73.00	2,795	38	0-

This list might be greatly extended by collecting the necessary data, but this seems unnecessary. All of these areas, and also the areas of the Manchester, England, water works from LakeThirlmere, and of the

Glasgow supply from Loch Katrine, not only have permanent populations often with villages, sewers and sewage disposal systems, but it is well known that they are open to summer visitors, wagons, automobiles and bicycles. In addition to the country roads, new and excellent roads are often most attractive to visitors, and they are used by great numbers of people each year. Thousands of automobiles pass over the roads around the Croton reservoir every fine day in summer. Boating is permitted, and on some lakes used for water supply excursion and other steamers ply.

In all of these cases water considered to be of good sanitary quality has been obtained as a result of the purifaction resulting from storage of the water in the light and without filtration.

Filtration will, no doubt, be applied to the Croton water at an early date, and to some of the other supplies in the list. Filtration is principally desirable to improve the physical properties of the water. It may be questioned whether, from a strictly sanitary standpoint, it would be justified for even the Croton supply at this time.

Removing all population from the catchment area so as to be able to say that there is no human being living upon it, and no pollution of the water, is an ideal frequently contemplated, but rarely reached in practice, particularly in more densely populated parts of the country. As a practical proposition of obtaining it is not necessary. Abundant experience has demonstrated the possibility of obtaining thoroughly satisfactory water supplies from areas having considerable permanent population, and traversed by roads and railroads.

If the excrement from such population were mixed freshly with the water as it flows into the pipes the water would be polluted in many cases so as to be unfit for use.

The actual conditions are quite different from this, however. In the first place, most of the polluting matters are deposited on or in the soil, and are purified by it under the most favorable conditions, and only the purified effluent from them ever reaches the water courses. The purifying power of the soil in sewage treatment is well known. Wherever the soil is pervious the polluting matters, especially from a scattered rural population, are distributed in it in such a way as to take most complete advantage of this purifying action. With steep slopes, impervious soils, and with frozen ground, this purifying action is less complete and frequently is not to be depended upon.

A second line of defense is afforded by the storage of the water in a large reservoir holding many days', and even months' or years' supply. The harmful organisms transmitted by water in temperate climates only exists for a limited time in the water of the reservoirs. They never reproduce or increase in numbers, but, on the other hand, gradually die out and lose their virulence. Some of those who have studied the matter carefully hold that it is practically impossible for infectious material to exist for more than twenty days in stored water. It may be questioned whether so short a limit is to be accepted as sufficient under all American conditions, but at any rate the polluting matters rapidly disappear, and water stored in a large reservoir is comparatively free from infection.

With only a scattered rural population and with storage in a large reservoir, these two elements are all that are necessary to make water safe from a sanitary standpoint, and certainly they are more than sufficient where, instead of a scattered rural population, there is only a small camping population of necessary employes and visitors.

In case it is necessary other means of defense against infection carried by water are known and well understood, and can be applied at moderate expense, but their consideration in this case seems unnecessary.

Park Rules

In the case of the proposed Hetch Hetchy reservoir and the raised Lake Eleanor it may be assumed that the present park rules preventing littering of the ground with rubbish and polluting the streams in any way will remain in effect, and no modification of, or addition to, those rules need be made for that part of the park which is in the catchment area of the proposed supply. If permanent hotels or camps having sewers should be established it would be proper that sewage purification works should be provided and required. Steamers and launches plying upon the lake might reasonably be required to carry suitable vessels for excrement, to be emptied and disposed of under suitable inspection. Such regulations have been made in the case of steamers upon other public water supplies, and they involve no very serious expense or hardship to those operating the boats.

So far as the supply of water was drawn directly from the dam at Hetch Hetchy and from the dam at the outlet of Lake Eleanor, all water used would be drawn from stored water, and the above suggested provisions would be all that would be necessary to impose in addition to those which are in effect under present conditions. In other words, no limit whatever need be placed which does not now exist on the use of the park for camping purposes. There is further no sanitary reason why roads should not be built along the reservoir and about it, as found feasible, and it would be permissible so far as the water supply is concerned to establish a reasonable number of hotels and permanent camps near it, and to operate steamboats and launches upon the waters of the reservoir.

It is assumed that all rules now in force, or in future established in the park, would be equally applicable to that part of it in the catchment area used for water supply.

And it is further assumed that the superintendent of the park would make from time to time such special regulations respecting sewage from steamers upon the lake, sewage of hotels, and any other matters that might develop, not covered by the present rules, as were reasonably necessary, and as were suggested and requested by the proper authorities of the City of San Francisco.

Water Used Without Storage

There are two general methods that might be used for utilizing the water:

By the first the water would be carried all the way from the reservoir in closed conduits, and protected from pollution at every point.

By the second the water would be allowed to flow in natural channels for a part of the distance.

I am not informed certainly as to which of these systems will be used, and this report is therefore made broad enough to cover both conditions.

In case the second method should be followed, that is to say, in case the intakes, or either of them should not be placed at the main reservoirs, but at some point on the stream below, then the water taken from that part of the catchment area tributary to the intake, but not tributary to the main dam, would not have the advantage of storage; and such part of the catchment area might properly be subjected to increased supervision and care.

The additional care would apply particularly to parties camping directly on the banks of the stream, and it would be proper to take extra precautions to prevent the direct discharge of waste materials into the streams by such parties.

The climate is favorable to safety in this respect, as during the camping season the ground is dry, rain is rare, sunshine is bright and continuous, and there is every chance for infectious materials deposited in and upon the ground to be rendered innocuous by natural agencies before the fall rains come to wash them into the streams. Nevertheless, there would be remote possibility of early fall rains which would wash such matters into the stream, and in view of this it would be well to exercise some additional supervision over this area.

It is assumed that the water will be used entirely in its raw state without treatment. There is no reason why the water from the proposed Hetch Hetchy reservoir or from Lake Eleanor when raised should not be so used.

There is the consideration, however, that in order to deliver the water in San Francisco in as good condition as it will exist in the reservoirs it will be necessary to carry the water always in closed conduits, to store it always in closed reservoirs, and to take various other precautions along the whole line to San Francisco. These precautions will cost a certain amount of money and it may be that it will prove to be better business, and in other respects more satisfactory, to handle the water by simpler methods, with less expense, storing it in open reservoirs, where this is inconvenient, and then filtering the water before it is finally distributed in San Francisco. Filters for this purpose should be operated at a rather high rate, without coagulant, and the cost of filtering would be small.

If this were done then that part of the area tributary to the intake below the main reservoir would not require any extra precautions and all parts of the area could be treated on the same basis.

Joint Use of Lands for Water Supply and Park Purposes

Granting the desirability of keeping certain areas free, or substantially free, from population, for the purpose of drawing public water supplies from them, and of keeping certain areas free from population for the purpose of using them for parks, the park areas being selected with reference to their natural beauty and facilities for camping and use by the people, there seems to be no reason why these two classes of areas should be kept separate. The use of an area for one purpose does not interfere appreciably with its use for the other purpose, and from the standpoint of conservation and the fullest use of the resources of the country there is every reason why the two uses should be combined as far as it can be done advantageously, and the same area used for park purposes and for water supply purposes.

This idea has been carried out in many cases where catchment areas, or parts of the catchment areas, have been acquired by cities for the purpose of protecting them from pollution, and have afterwards been thrown open to the public, frequently with the construction of splendid drives and walks through them, and without detriment to the quality of the water supply derived from those areas.

I will not attempt to discuss the advantages and disadvantages of flooding the Hetch Hetchy Valley from the standpoint of the park, the flooding of the swamps in the valley which now produce swarms of mosquitoes, and which would be eliminated by the flooding, the increased accessibility of the park by reason of the roads necessarily built in connection with the construction of the water works and the possibilities of going through so much of the valley in a gorge by boat.

The climate of the Yosemite National Park is very dry during the tourist season. Such water as is now there is one of the greatest elements in its natural beauty. Increasing the amount of such water by the construction of a large reservoir, forming a lake of considerable proportions accessible to visitors, is a matter which deserves serious consideration.

As to the Desirability of the Tuolumne Water as Compared With a Filtered River Water Supply

The Tuolumne water from a storage reservoir built in the Hetch Hetchy Valley, or from the raised Lake Eleanor, with other tributaries of the Tuolumne River diverted to it, or from both of these sources, will be softer than the filtered river water supply. The best river water would be that obtained from the Sacramento River, and this would probably be two or three times as hard as the Tuolumne water.

The Tuolumne water would be soft, and its softness would be permanent. There is no reason why it should be greater after a hundred or a thousand years than when the reservoirs were first built.

The hardness of a filtered river water supply, on the other hand, is certain to increase with increased use of the river for irrigation. The San Joaquin River water before the country was settled was probably not very different in character from the Sacramento River water. As a result principally of irrigation operations it is already so highly mineralized during a part of the year that it is no longer desirable as a source of public water supply. It is probable that the time will come when the Sacramento River water will be used for irrigation to as great an extent as the San Joaquin River water is now used, and even to a much greater extent. The Sacramento River water will then probably become mineralized to a corresponding or greater extent, and will be less desirable than it now is, or it may become unsuitable for a public water supply.

From the standpoint of hardness and mineral matter the Tuolumne water is much more desirable than any river water supply available for San Francisco.

The Tuolumne water is a water of the greatest natural purity from the standpoint of organic matter, organisms and pollution of every kind.

The storage of the water in great reservoirs will have the effect of eliminating even such small impurities as there may be in the flowing water and of insuring the delivery of water of the greatest purity.

The Sacramento River water can be well purified by filtration, and with properly constructed and properly operated works good water would be obtained, but it must be admitted that there is a chance of failure to secure the best obtainable results at all times, either through some fault of design or construction, or lack of sufficient skill on the part of the management. Such lapses from the best obtainable results occur too frequently under our present system of municipal management in American cities. The possibility of their occurrence must be given due weight in considering the relative advantage of the waters.

Gravity supplies from upland areas having sparse rural populations have been, on the whole, the most satisfactory supplies used by large cities the world over, and when, as in this case, there is no permanent population upon the proposed catchment area, conditions are remarkably favorable, and the water to be obtained is certainly more desirable than any filtered river supply that can be secured.

December 4, 1911.

Respectfully submitted,

(Signed) ALLEN HAZEN.

BELOW THE INTERESTING PART OF THE HETCH HETCHY VALLEY.

View down the Poopenaut Valley and reservoir site, taken from a point of rocks on the Hetch Hetchy trail about one mile southwesterly from the Hetch Hetchy dam site. The dam site for this small supplementary reservoir is in a very narrow gorge in the distant center of the view. The new wagon road is to run up the left hand side of the valley. Flooding this valley floor would add to the scenic interest. The city desires the right to do this.

It is only a short portion of the Hetch Hetchy Valley that contains scenery of any special interest. Nearly all of it is comprised within the one mile covered in the photographs on pages 6, 10 and 12. The remainder is the ordinary deep canyon scenery of the Sierra rivers, grand, but much like that seen from the car windows of the Southern Pacific and Western Pacific Railroads. There is far less length and variety of interesting scenery in the Hetch Hetchy Valley than in the Yosemite Valley.

Use of Hetch Hetchy Will Preserve Other Camp Sites

(32) There is a shortage of storage capacity in the reservoir sites provided by nature along the Tuolumne River as has been shown in a report prepared recently by Mr. Grunsky, formerly City Engineer of San Francisco, and if the city does not store and make useful the surplus of flood waters, which now run to waste, and sometimes contribute to devastation on their way to the sea, others will seek in course of time at one point and another to impound them, for power or other possible uses. The Tuolumne Meadows have been often suggested as a possible reservoir site.

With the great height of dam at Hetch Hetchy now proposed there will never be need for building other dams or reservoirs at Tuolumne meadows or at any other site upstream from the Hetch Hetchy, save that in the very distant future it may be well to build a dam at the outlet of Vernon Lake and lakes further up on the same stream. There is a remote chance that if the city grows beyond the conservative figure that I have adopted, storage on Rancheria Creek and possibly on Poopenaut meadow may be needed in the very distant future—barely enough chance so that all water rights upstream from the confluence of Cherry Creek should be reserved in favor of the city.

Storage Farther Down the River

(33) Much of the surplus flood flow which the projected Hetch Hetchy reservoir with spill-way even at elevation 3850 could not contain can be conserved in reservoirs in the foot hills, such as are common about Denver, Fort Collins and Greeley, Colo., and of which Modesto and Turlock have built one already and are planning to build others. These lower reservoirs can catch water from the lower drainage not otherwise conserved.

Vernon Lake

(34) The city desires to now secure against all possibility of adverse possession, rights to Vernon Lake and its tributaries and hold these in reserve. Whenever the expense of even a low dam at Vernon Lake can be justified, the reservoir thus formed can be made useful for supplying a full cascade throughout the tourist season at the beautiful Wapama Falls.

THE TUOLUMNE MEADOWS.

About 24 miles up the river from Hetch Hetchy, 8,500 feet above sea level. Surrounded by high Sierras. An excellent headquarters camp ground for excursions to the summits.

Often suggested as a reservoir site, but unnecessary for conserving the Tuolumne flood waters if a suitable high dam is built at Hetch Hetchy; which site is far more suitable for conservation because of controlling a larger catchment area.

Tuolumne Meadows

(35) With all possibility of its use for a storage reservoir removed there is no reason whatever why campers should not for all time, utilize the Tuolumne Meadows to their hearts' content, without supervision or hindrance on behalf of the water supply, and there is no good reason why a hundredfold more visitors per year than have ever yet visited the Hetch Hetchy region should not enter and enjoy these meadows and the beautiful regions beyond, with their many little lakes, at the base of Mt. Lyell, Mt. Dana and others of the highest Sierras. Tuolumne Meadows has more advantages for campers and as a head quarters for those who would climb the summits of the high Sierras than any other meadow for many miles around.

Camp Grounds

(36) Dozens of little parks or meadows exist in the forest on mountains surrounding the Hetch Hetchy,—the writer last year noted three in the course of a day's trip to Smith's Peak,

made for obtaining a broad outlook over the Hetch Hetchy Valley and up the Tuolumne Grand Canyon. Each of these little meadows was at that time covered with flowers and good grass, well watered, surrounded by a beautiful forest and each was a "paradise for campers," and the city could not have the slightest objection to such occupancy within the watershed tributary to its water supply reservoir.

A Hotel Site at Hetch Hetchy

(37) There is an admirable site for building a summer hotel near to the proposed Hetch Hetchy dam site, and the city would welcome rather than hinder such use, for it is believed that familiarity with the quality and surroundings of such a source of water supply would help in maintaining the sense of civic pride and civic responsibility.

Subsequent to building the upper 12 miles of the tunnel, the drainage from any such hotel or any permanent camp can be led onto filter beds below the dam site and in the earlier years it can be made safe otherwise.

Not far from the entrance to the Hetch Hetchy is a broad meadow, high above the proposed level of the lake, on the borders of which camp space can be found for ten-fold the number that have ever yet visited this upper Tuolumne valley at one time, save on a certain Sierra Club excursion, unless they happen to be of the type of man who needs an entire valley to himself in order to really enjoy it.

Should the cities of Greater San Francisco be compelled to spend some ten million or twenty million dollars extra for another less desirable source of domestic water, simply in order that ten or twenty solitude lovers may have this beautiful valley mostly to themselves?

Poopenaut Meadows

(38) The Poopenaut Valley, on the main Tuolumne a short distance downstream from the Hetch Hetchy, can be available to campers so soon as the upper 12 miles of aqueduct tunnel have been built, but until that time campers should be excluded from the Poopenaut meadows and from the remainder of the possible catchment area downstream between the Hetch Hetchy and the Early Intake, but this small area is all so rugged and uninviting that no sanitary trouble from it appears possible during whatever time may elapse before the aqueduct is complete all the way to the Hetch Hetchy dam. It is conceivable that in the very distant future the Poopenaut meadows might become useful to the city for storing the water which in

wet years will waste over the Hetch Hetchy dam, and it should therefore be held in reserve for the use of the city, and the 80-acre tract of patented land purchased whenever there is favorable opportunity.

By the relief map on page 3 one can get a good idea of the remarkably small drainage area tributary between the early intake and the Hetch Hetchy dam.

It appears best to make clear regarding the possibilities of future power development, that no restriction should be imposed which will prevent making useful for power the water released for the irrigation priorities by releasing this water just below the Moccasin Creek power house instead of at the several reservoir dams. The only change required for this would be the addition of a foot or two to the diameter of the tunnels upstream from Moccasin Creek, and a large additional amount of power could be gained.

Quality of Present Supply to San Francisco

The ground waters from Sunol and Pleasanton constitute nearly half the entire supply, and being purified by natural filtration, are exceptionally attractive in appearance, white and brilliantly clear, but as elsewhere stated rather too hard.

The surface supplies from the Peninsula sources are given exceptionally good care at the gathering grounds of Crystal Springs, Pilarcitos and San Andreas, and intercepting drains have been built for diverting surface drainage coming from the streets and populous regions near Lake Merced.

The bugs and algae from the surface waters are carefully strained out through cotton cloth near the Honda reservoir, with a care not often given to public surface water supplies and so this surface water reaches the consumer in an acceptable condition, but in future with the general tendency of the public to be more exacting as to the quality, all of this surface supply, including whatever is gathered in the Calaveras reservoir, will require filtration.

The present quality of the water furnished by the Spring Valley Water Company is, I believe, thoroughly wholesome and safe, from the sanitary point of view, but mountain water will be softer, and better and to be kept at its best, will require separate delivery as elsewhere explained.

PROPOSED GENERAL ORDER OF WATER SUPPLY DEVELOPMENT.

Spring Valley Purchase

(39) In further compliance with the request of the Secretary of the Interior for a statement of the proposed use and development of the Hetch Hetchy and Eleanor sources and in explanation of the fact that the plans herewith submitted all connect to the existing reservoirs and delivery mains of the present water supply companies, it should be explained that I have been informed by you and by the special water committee, appointed by the Board of Supervisors, that the city proposes to take the initiative in acquiring by purchase or by condemnation all of the property of the Spring Valley Water Company now used or capable of use for supplying the city with water. It is hoped that a purchase as between a willing buyer and a willing seller can be made, both parties benefiting by the trade.

The Spring Valley water, altho excellently cared for, plainly is not of the most superior quality. It is hard, and the Merced water in particular is weedy and unattractive, as anyone can see by visiting the lake margins and the intake wharf. The upper end of Capital Spring Reservoir at certain seasons of the year presents undesirable conditions.

A surface water held long in storage in the warm temperature and almost constant sunshine of the California climate appears to invite more luxuriant aquatic vegetation than is found in the supply reservoirs of eastern and northern cities, and even the Hetch Hetchy water, notwithstanding its near approach to sterility in the future mountain reservoir, will best be delivered direct from the pipes and small equalizing reservoirs or standpipes, using the large open reservoirs chiefly as a safeguard, after the future by-passes around Crystal Springs and Lake Chabot have been built.

It is obvious that it is not necessary that the new aqueduct connect with the Spring Valley distribution system and obvious that even the great Crystal Spring Reservoir is not strictly essential to the Hetch Hetchy project, for Lake Chabot can be enlarged at small cost to larger capacity than Crystal Spring and a shorter aqueduct built across the bay from Alameda to Potrero Point, and an excellent distributing reservoir capable of holding more than five times as much as all of the present Spring Valley distributing reservoirs combined, or equal to alone supplying the present rate of draft for four and a half months in case of a break in the aqueduct, can be built at small cost, admirably located 38.5 feet above city base only three and one-half miles from the San Francisco City Hall, in Glen Park, the valley of San Miguel Hill, as shown elsewhere in this report. But as for the best good of all concerned, it is desirable that the new supply join on to the present system and that the great reserve on the peninsula given only in the Crystal Spring Reservoir be secured. And I have designed the city end of the Hetch Hetchy aqueduct in the belief that this purchase will be effected, and that the much better mountain water will be used, while the peninsula sources will be held in reserve and perhaps be made useful meanwhile as an aid to irrigation. Each million gallons daily can irrigate nearly a square mile.

If the terms of sale were already settled, some months would necessarily elapse before this transaction could be competed and the transfer of title made. There is various litigation now pending between the Water Company and the city and some time may elapse before the terms of purchase can be agreed upon.

Under charter provisions, if proceeding by purchase, the terms of purchase must be submitted to the voters at a general election. Moreover, administrative machinery must be created for the management of an enterprise new to the city and this may require additional state legislation and additional delay. It appears hardly possible that all of this can be accomplished within less than a year's time.

People's Water Company Purchase

(40) Across the Bay it appears that the people are determined that the municipality should own the water works and I am informed that preparations for condemnation suits with this in view have been already begun. The situation is the more involved because the one water company now supplies some fifteen separate communities.

Formation of a Metropolitan Water District

(41) It is confidently expected that in the near future definite and important progress can be made upon the formation of a metropolitan water district, including with San Francisco the rapidly growing communities in San Mateo County and the group of cities that may be described as Greater Oakland, all of which together now consume about two-thirds as much water as San Francisco.

The members of this metropolitan water district would share all of the expense incurred in providing the supply and in delivering it into the chief storage reservoirs, the water district conducting as it were a wholesale business in water supply, while leaving to each of the several municipalities the retail business of supplying its own citizens thru its own distribution mains, very much as is done in the case of the Boston Metropolitan District.

Immediate Construction of Calaveras Reservoir and Bay Head Conduit

(42) Various legal contingencies are possible which may delay the city in obtaining title to the water works property; meanwhile, more water is desired; and various sections of the city are suffering from lack of water in the pipes and other, growing sections still lack water pipes; therefore the City of San Francisco is seeking to devise a plan by which, if acceptable, immediate progress shall be begun by the Water Company prior to transfer of title, in extending its mains and in building certain structures that will have both an immediate value for supply in the impending shortage and a permanent value in bringing the Tuolumne supply to the city. The two most important features of this plan are the immediate construction by the Spring Valley Water Company of its proposed Calaveras Reservoir and the simultaneous construction by the Water Company of a tunnel and steel pipe from the Sunol Valley, below the Calaveras dam, extending across the head of the bay to the Crystal Springs Reservoir, which tunnel and pipe will form a portion of the future Tuolumne aqueduct system, shown on the accompanying plans.

Safeguard in Calaveras Reservoir

(43) As a safeguard against shortage of water in case of low rainfall in the near future, and also as a future safeguard against interruption of the pipe across the San Joaquin Valley, or an accident in any part of the tunnel system, the city would propose that this Calaveras Reservoir be constructed of greater capacity than would be required to equalize the runoff from its own watershed, in order that this surplus storage from occasional floods may be in reserve for emergencies.

Plans were prepared by me some months ago at the request of the Spring Valley Water Company for building this reservoir to a flow line at elevation about 783 feet above sea level, at which elevation their contour surveys show that it would contain about 46 billion gallons, an amount equivalent to delivering 100 million gallons daily for about one and a quarter years.

The following illustrates how much Calaveras would add to the safety against interruption:

The proposed capacity of the Calaveras Reservoir with flow line at 783 is............46 billion gallons
The capacity of the Crystal Springs Reservoir, present elevation of 280[*] is said to be. . 19 billion gallons
The San Andreas Reservoir is reported to contain .... 5.5 billion gallons
The Pilarcitos is reported to contain about. . 1 billion gallons
And reckoning that Greater Oakland will join after acquiring Lake Chabot, which is said by the water works superintendent to contain .... 4.8 billion gallons
there would be a total storage when all these reservoirs are filled of.............76.3 billion gallons

Probably not all of this would be available. It is stated that considerable silt has accumulated in the bottom of Lake Chabot, and it is seldom proper to draw off a reservoir to the very bottom.

Obviously, storage reservoirs cannot be kept at high water mark all the time while being efficiently used, but the most of these reservoirs are of exceptionally great capacity in proportion to the run-off of their catchment areas, being so designed for the purpose of tiding over a series of years of low rainfall.

Supposing them only one-third part full at the time of an accident, contents of 25 billion gallons would still be sufficient to supply 75 million gallons daily (which is ten millions more than all the communities on both sides of the Bay are now using) for a period of 333 days, and would supply them for a full year, and longer when the run-off from their catchments into these reservoirs is also reckoned in.

Altho an exceptionally large reserve is needed for safety against water famine under the very remarkable cycles of low rainfall that sometimes occur in this part of California, this will be provided for in the mountain reservoir, leaving the chief value of local reservoirs for emergencies (or irrigation).

Additional Future Reserves Against Accident to the Hetch Hetchy Aqueduct

(44) In future when the cities have grown and when

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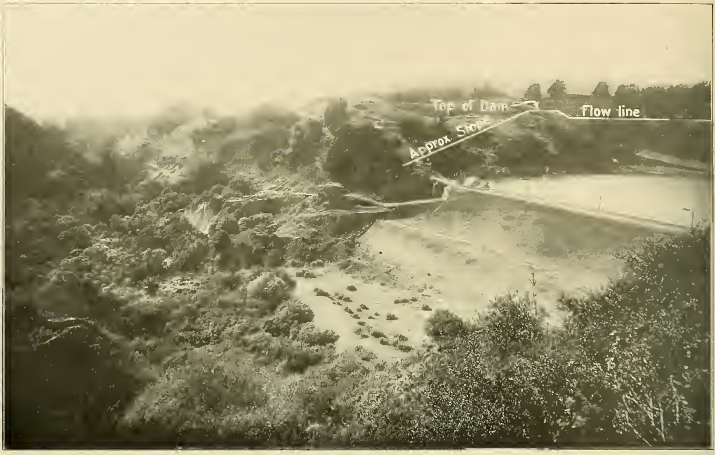
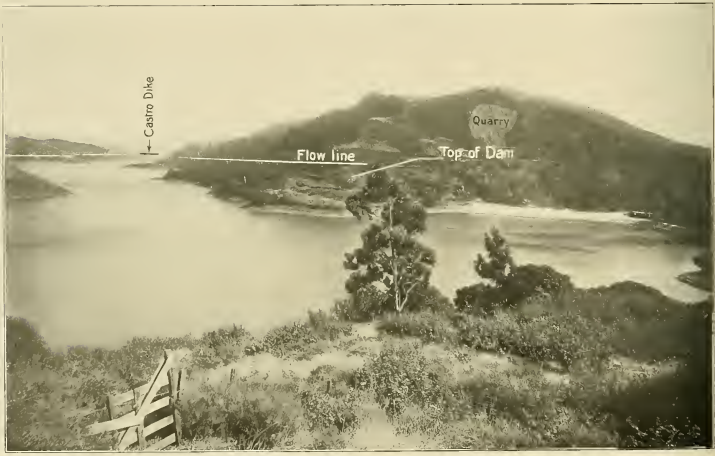
[*] By later information from the engineer of the Spring Valley Company, the present top of the main dam reduced to mean sea level datum is at 282.0; on this a rather light parapet wall has been built, with top at 292.61. This reservoir can be drawn down to 181.63. The contents between 292.61 and 181.63=111. feet is 22,778 million gallons.



THE PRESENT SAN LEANDRO DAM OF LAKE CHABOT IN RELATION TO INCREASED HEIGHT PROPOSED
From the Public Highway, looking Northerly.



SITE OF THE PROPOSED HIGHER SAN LEANDRO DAM, LAKE CHABOT
Looking Southerly. The white surface at the right center of the view is the concrete face of the present dam.

the draft has increased, a larger reserve will be needed. Whenever deemed expedient, it is believed practicable to raise the Crystal Springs dam so as to give a much larger capacity. Its designer built this dam with much extra thickness of base for this purpose. From a rather hasty examination of the dam and of conditions at its north end, a future height of flow line at elevation 300 or 305 above mean sea level would be reasonable.

The flow line of Lake Chabot can be raised 115 feet with absolute safety, by plans presented later in this report, thus adding about 32 billion gallons to its present capacity.

Outside of these additions in Crystal and Chabot, it is feasible, in the course of pushing the Hetch Hetchy aqueduct eastward from the cities toward the Hetch Hetchy source, to first construct the San Antonio reservoir, of nearly 12 billion gallons capacity, 1½ miles easterly from where the Calaveras water enters the aqueduct, and 7 miles farther eastward the water of the Arroyo Valle reservoir of possibly 13 billion gallons capacity, could be picked up. All of these storage reservoirs lie west of the crest of the Mt. Diablo range.

Reservoirs previously enumerated, Crystal Springs, Andreas, Pilarcitos, Chabot, Calaveras, deducting silt, say	75 billion gallons
Add for San Antonio, flowage to elevation 450	11.8 billion gallons
Add for Arroyo Valle, flowage 150 feet deep	13.7 billion gallons
Total storage reserves, when at high water mark, and exclusive of raising Crystal and Chabot	100 billion gallons

After the Hetch Hetchy aqueduct is once brought into use, the natural policy will be to use the better, softer water and to either waste the harder water from the near-by sources or divert it temporarily to agricultural purposes until again needed for domestic supply, and therefore each of these reservoirs enumerated above would seldom or never be drawn so low in future as under present conditions.

Three-fourths of the aggregate quantity that the above contain (exclusive of raising Crystal and Chabot), would supply a daily draft of 200 million gallons for a full year, or would supply 400 million gallons for six months, and beyond this the city could still draw water from the Pleasanton-Sunol sources, and draft would still be possible from the Bay shore gravels, and the run-off from the several catchments to these reservoirs would add an important amount.

Additional Storage Reserves Possible

(45) Raising Lake Chabot would add 32 billion gallons
Raising Crystal Springs from elevation 283 to
305 would add about . . . . 12 billion gallons

Adding the reservoirs enumerated above makes a
total reservoir capacity of . . . . 144 billion gallons
which, if about two-thirds full at time of an assumed interruption of the aqueduct by accident, earthquake or war, would supply 400 million gallons daily for 360 days, or about a full year in addition to the small local yield.

(46) It is of interest to note that the method described above of building the Calaveras Reservoir, the San Antonio Reservoir and the Arroyo Valle Reservoir, and bringing all these waters to the Crystal Springs Reservoir by means of tunnels from Valle westward through the hills near Irvington, and thence by a larger steel pipe across the valley at the head of the Bay, is substantially the same as long ago proposed by Mr. Schussler, the engineer under whose able supervision the Spring Valley properties have been acquired and its works built up. The only important difference is a little variation in the location of the tunnels and an increase in the diameter of the tunnels and of the pipe in order to make room for the Hetch Hetchy water later.

Tuolumne vs. More Reservoirs

(47) Today it is difficult to state whether following the construction of the Calaveras Reservoir, the San Antonio Reservoir should be built, and after that, the Arroyo Valle Reservoir, the tunnels being meanwhile pushed easterly of their full future size for taking in, one after the other, the waters from the Calaveras, San Antonio and the Valle, the Hetch Hetchy, Eleanor and Cherry supplies, or whether for the present and for perhaps fifty or a hundred years to come, these two reservoir sites at Antonio and Valle should be passed by, without building their dams, in order to devote the available funds to bringing the better water from the mountains to the several cities around San Francisco Bay at the earliest practicable date.

Judged purely on its financial side, presuming that the owners of agricultural land on the Niles Cone could interpose no obstacle to the impounding of the flood waters from these limited portions of the Livermore Valley upstream from the Calaveras, Antonio and Valle dam sites because of the farmers' need of an occasional outflow of flood waters through the Niles Canyon to replenish their ground water supply, it is plain that there would be a saving of cost from developing these reservoirs, the dams for which are relatively inexpensive and which would put off for a few years the paying of interest upon the large sum of money involved in building the Hetch Hetchy dam and the aqueduct easterly from Valle.

Assuming, as is probable, that the increase in water consumption for the greater San Francisco five years hence will be at the rate of nearly three million gallons daily over the consumption of the preceding year, and taking the rough preliminary figure of five or six million gallons daily as the dependable yield from San Antonio watershed, and six or seven million gallons daily as the dependable yield from the Valle watershed, the building of these two reservoirs might permit the building of the Tuolumne works to be deferred four or five years and an amount would be saved in interest that would build the dams two or three times over and leave them forever after as a reserve for accidents or as an aid to agriculture.

On the other hand, it is plain that many citizens on both sides of The Bay earnestly desire the earliest reasonable introduction of the Hetch Hetchy water, which will test at only about 20 on the scale of hardness as against about 100 for the present Spring Valley sources, and presents other attractive features.

Los Angeles, Seattle and Portland have each secured their bountiful supplies of mountain water, and doubtless a bountiful supply of mountain water for the San Francisco Bay cities would add to their attractions for newcomers and encourage the investment of new capital.

Additional Supply from Present Sources

(48) The additional dependable quantity of water that can be taken from the present sources in case of a series of years of extremely low rainfall, or in case of a decision unfavorable to the water company in certain adverse claims that have long been agitated in regard to diverting the supply from the underground waters of the Niles Cone and Pleasanton, is, of course, one of the elements of chief importance in forming an opinion upon the date when the city must go to the Sierra for an additional supply.

There is much reasonable foundation for a belief that the water supply corporations on both sides of the Bay have deceived themselves in over-estimating the extent of their undeveloped resources which can be profitably and dependably brought into use, and it is apparently a matter of human nature the world over to be too optimistic about water supply from underground. This is a matter which will be discussed in various reports based on recent extensive collections of data to be submitted later.

Investigations to be Continued

(49) A painstaking investigation of the capacity for further development in the sources now owned or controlled by the present water supply corporations has already been far advanced, as is shown by the reports soon to be placed on file with the Board of Army Engineers for the information of the Secretary of the Interior.

The question of how much further the sources which chiefly supply the underground waters of the Niles Cone may be stored and diverted is one QUITE AS MUCH FOR LAWYERS AS FOR ENGINEERS, AND ONE OVER WHICH THERE CAN BE BITTER AND ENDLESS DISCUSSION, and the question of how far one may increase the rate of draft of ground water near the Alvarado bay shore without spoiling this source by sucking in salt water, as has happened in connection with the water supply of Brooklyn, N. Y., where some sources have suffered from overpumping, is, without proper data for its determination, a difficult one. The best information that I can obtain today SHOWS THE DANGER POINT ALREADY NEAR, and a large area near the pumps where the plane of saturation today stands below sea level.

The question could be precisely answered only by one or two years of painstaking study and a very liberal expenditure for small test wells in which to trace out the contours of the water table, just as has been done on Long Island, New York, in studying the Brooklyn supply, and by a test case in the courts.

I do not believe it worth while to carry this investigation of extension of local sources much further, but think it more profitable to concentrate upon the Hetch Hetchy studies.

From conference with members of your Special Water Committee and members of the Board of Supervisors, and other officials and well-informed citizens, it has become plain to me that public opinion will support incurring the expense of an immediate, vigorous and thoro investigation and preparation of surveys, test pits, borings and plans for the Tuolumne River supply as soon as a decision is reached on behalf of the United States Government in regard to granting the requests of the city expressed on the first sixty pages of this report.

Scope of Preliminary Studies and Work on Hetch Hetchy Aqueduct Desired Immediately

(50) Altho a careful engineering reconnaissance has been made by the writer and by expert assistants along the entire Hetch Hetchy aqueduct line, covering both the surface features and an expert geological study, (all of which investigations appear to demonstrate the engineering feasibility of the entire project), it is now desirable to carry the investigation much farther in order to thoroly test the quality of the sub-strata of rock that would be penetrated by the tunnels, and for this purpose to make hundreds of diamond drill borings along the location already selected, and upon such varients from this location as may be suggested in the course of these diamond drill borings and the progressive geological interpretation, and the permission of the Interior Department is desired to enter on national park lands and other public lands for this purpose under any reasonable restrictions or supervision.

While it may prove entirely feasible to follow the aqueduct tunnel location already selected, which is shown on the accompanying plans, there will doubtless be found, off to one side or the other from this preliminary line, rock which can be tunneled more cheaply, with a smaller amount of temporary timbering, or with less infiltration of water, or rock which is more easily drilled or which will break into better shape when blasted. In the case of the New York aqueduct from the Catskill Mountains region, now under construction, as a result of such diamond drill borings and geological studies, it was found expedient long after the work of construction had begun, to shift some fifteen or twenty miles of the line and to pick out an entirely different site for crossing the Hudson River, and as a result of the careful preliminary engineering study with the aid of geologists and diamond drills, all parts of that work have been pre-eminently successful in freedom from accidents due to "bad ground," heavy inflow or unexpected difficulties.

It is important for all of these San Francisco Bay cities to continue the work of thoro investigation and reach conclusions upon the course and the cost and the difficulties of the supply from the Hetch Hetchy, in order to determine how far the draft from local sources should be extended before softer and purer water is brought in from the mountains.

There can be no question that some day the cities must have water from the mountains, the only questions are, how soon? and which source first?

Studies and Work on Roads, Etc.

(51) Meanwhile, also, much surveying will be necessary to lay out the best possible line of roadway, and the most favorable grades for bringing construction material, men and supplies to the tunnel shafts and adits, and these road plans must be worked out not only for temporary construction purposes, but for roads so located and built that they may be cheaply maintained, running as near to construction shafts and tunnel portals as practicable, and forever available for quick access to these points in emergencies.

One of the most difficult problems about the Hetch Hetchy dam or a large masonry dam at Lake Eleanor or Cherry is that of building the road or railroad along the precipitious canyon side and up the steep grades, for cheaply hauling in the vast quantities of cement and subsisting 500 or 1,000 workmen. One reason why past surveys have been so crude and have progressed so slowly is the extreme difficulty of crawling along on these steep slopes at grade with camp site or drinking water a thousand feet or more below.

Following the final decision and selection of the aqueduct location much time will be occupied in securing rights of way for aqueduct and road.

The City of San Francisco has already invested more than one and a quarter millions of dollars in water rights and reservoir sites at Hetch Hetchy, Eleanor and Cherry, and should be similarly ready to purchase and protect the rights of way and all of the sites needed for the full utilization of these mountain sources.

I am told that it is the purpose of the city to carry forward all of this work of investigation immediately and diligently, until the whole series of structures have been planned, all rights of way secured, and I am convinced that it is wise to do this all well in advance of the time when it will be come necessary to begin the work of tunneling east of Arroyo Valle, which is the most easterly and the last of the coast range sources that can be picked up on the way to the Hetch Hetchy.

Concerning the date for building the roads above described, it is quite possible that your citizens may be ready to incur the expenditure of building these immediately, and that also willingness will be shown to begin work on the Hetch Hetchy dam earlier than would be strictly necessary if the date when additional water will be needed was the only consideration.

There may be good reason in doing this in order to thoroly establish these water rights and in order to open up this beautiful region to its citizens and thus bring about a better popular appreciation of the upper Tuolumne source and its manifold advantages.

Temporary Power Plant

(52) Following the explorations and road-building described above, one of the first acts in the construction would be the building of a temporary plant for supplying electrical power for purpose of driving air compressors, for operating various tunneling machinery, rock crushers, concrete mixers, hoists, derricks, construction railroads, etc., etc.

The precise location that is most favorable for building this temporary power plant is not determined, but the site that is most promising today is only a short distance downstream from the mouth of Cherry Creek, on the main Tuolumne River, where a diverting dam of temporary character would be built perhaps 25 feet high, diverting water from the river into a hillside canal or wood stavepipe beside the wagon road which would follow downstream along the contour of the canyon until fall is obtained sufficient to give the required amount of power from the summer flow that may be made available.

From this power station a pole line and transmission wires would be run along the new main highway already described, with points for delivery of power at each tunnel shaft, each portal and at the dam, and also to branches for furnishing power to the field shops for building the steel pipe line across the San Joaquin Valley, and to the power shovel for excavating the trench in which this pipe would be laid.

In order to insure a sufficient quantity of water to operate this temporary power plant during the months of September and October, or whenever the river flow is smallest, it may be found necessary to build a storage dam of a temporary character, at one of the city's reservoir sites. It is possible that the cheapest and best opportunity for temporary power plant will be found a short distance downstream from the site of the Hetch Hetchy dam, and that the best means for storing sufficient water for this temporary plant will be a temporary dam at the outlet of the Hetch Hetchy Valley, so built as to also serve as a cofferdam for diverting the water while excavating for the deep, narrow part of the foundation of the main dam.

Time Required for Building Main Dam

(53) It is important that the main Hetch Hetchy dam be begun at the same time with the tunneling for the main aqueduct, and that this dam be completed to its full height. The working season at this altitude is brief, whereas work in the

tunnels can everywhere be carried on the year round; and moreover, it appears desirable that all disturbance incident to the construction of the dam be gotten thru with and the surroundings cleaned up, replanted and restored to a state of Nature as speedily as possible, under the guidance of some skillful landscape architect.

Under the best of conditions, with a temporary railroad for hauling in the vast quantity of freight required, this dam would probably require at least three summers for its completion, and one year or more, probably two years, before the dam is begun will be required for building the extremely difficult and costly road into the Hetch Hetchy Valley and dam site.

Time for Building Scenic Road

(54) The construction of the proposed scenic road could best be begun when the dam is nearly completed, the drills, derricks and other plant being transferred from the dam to the tunneling and heavy side-hill work on the scenic road, the workmen remaining quartered in the construction camp at the dam.

Time Required for Building Aqueduct

(55) Under the most favorable conditions, all of this tunneling east of the Arroyo Valle may be expected to occupy a period of at least five years from start to finish; for some of the tunnels are exceptionally long and there is a point beyond which it will not pay to add plants for working a great number of the shorter tunnels simultaneously.

The steel pipe portion of the aqueduct, comprising about 44 miles across the San Joaquin Valley and two or three siphons across valleys, could be all erected within two years, if part of the material were accumulated in advance; therefore the beginning of this portion of the work can be delayed.

Need of Beginning Soon

(56) I am led to believe it probable that with the utmost reasonable development of the sources on both sides of the Bay, owned by the Spring Valley Company and by the People's Water Company, it will be necessary to begin construction work vigorously on the Hetch Hetchy supply inside of five or ten years and it may prove expedient to begin much sooner.

I am not able to make so close an estimate of this date today as will be possible later, after some of the doubtful problems as to the amount which may be developed from subterranean sources and the water rights of the Niles Cone, have been more completely worked out, from the legal standpoint as well as from the engineering standpoint.

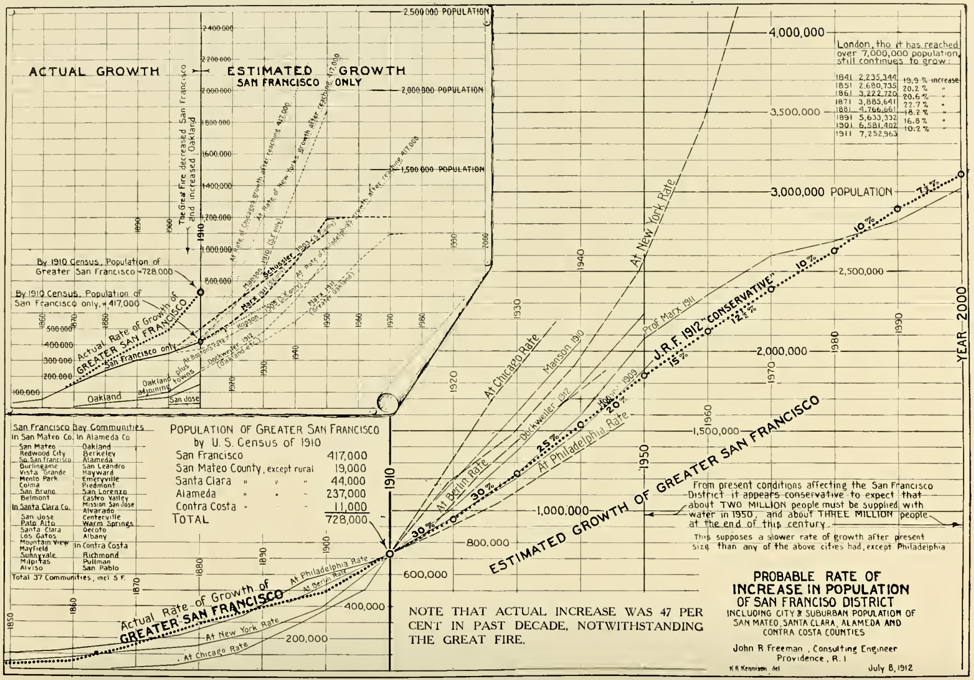
I have no doubt whatever that the work of investigation and preparation by means of surveys, diamond drill borings, test pits, road construction, etc., as outlined in the previous pages, should be begun not later than next summer, or as soon as the city can obtain the sanction of the Interior Department or other necessary legislative authority for the various works which the city proposes and which were described in the opening pages of this report.

Investigations of this kind, if thorough, are costly, requiring an expensive corps of men; but commonly this cost is saved several times over in the progress of the work. It now is *important that the scattering of effort and expense over detailed investigation of hopeless projects should cease*, and the work settle down to the one source which promises to be best and by far the cheapest, particularly when the long future is considered.

From my own investigations, which have now been in progress, off and on, for more than two years, I am convinced that the Hetch Hetchy is much the best mountain source for the San Francisco District, and I am also convinced that the city in course of its development of works for water supply will make the Hetch Hetchy Valley more beautiful, and a far more useful instrument of pleasure than it is today.

The preceding pages are believed to cover all of the information requested by the Secretary of the Interior to be furnished to the Advisory Board of Army Engineers on July 15, 1912, by his letter of May 28th, quoted at the beginning of this report, but in order to make more plain the considerations which have guided your engineer in the design of the works proposed, additional data supporting the city's case, which under the Secretary's order are to be filed upon August 1, 1912, so far as it has been possible to set them in order for publication in a limited time, are now presented on the following pages. Those who have climbed canyon walls in the Sierras will understand how slow and expensive are surveys for studies of this kind. With more time a more complete report could have been presented and closer estimates of cost, but I cannot conceive it possible that another year, or even five years, of surveying and estimating would change any of the fundamental features of the project now presented, all of which follow good precedents.

Respectfully submitted,
JOHN R. FREEMAN,
Civil Engineer.



San Francisco Bay Communities

In San Mateo Co.	In Alameda Co
San Mateo	Oakland
Redwood City	Berkeley
So. San Francisco	Alameda
Burlingame	San Leandro
Vista Grande	Hayward
Menlo Park	Emeryville
Colma	Piedmont
San Bruno	San Lorenzo
Belmont	Castro Valley
In Santa Clara Co.	Mission San Jose
	Alvarado
San Jose	Centerville
Palo Alto	Warm Springs
Santa Clara	Decoto
Los Gatos	Albany
Mountain View	**In Contra Costa**
Mayfield	Richmond
Sunnyvale	Pullman
Milpitas	San Pablo
Alviso	

Total 37 Communities, incl S. F.

POPULATION OF GREATER SAN FRANCISCO by U. S. Census of 1910

San Francisco	417,000
San Mateo County, except rural	19,000
Santa Clara " " "	44,000
Alameda " " "	237,000
Contra Costa " " "	11,000
TOTAL	728,000

London, tho it has reached over 7,000,000 population, still continues to grow:

1841	2,235,344	19.9 % increase
1851	2,680,735	20.2 % "
1861	3,222,720	20.6 % "
1871	3,885,641	22.7 % "
1881	4,766,661	18.2 % "
1891	5,633,332	16.8 % "
1901	6,581,402	10.2 % "
1911	7,252,963	

From present conditions affecting the San Francisco District it appears conservative to expect that about TWO MILLION people must be supplied with water in 1950, and about THREE MILLION people at the end of this century.

This supposes a slower rate of growth after present size than any of the above cities had, except Philadelphia

NOTE THAT ACTUAL INCREASE WAS 47 PER CENT IN PAST DECADE, NOTWITHSTANDING THE GREAT FIRE.

PROBABLE RATE OF
INCREASE IN POPULATION
OF SAN FRANCISO DISTRICT
INCLUDING CITY & SUBURBAN POPULATION OF
SAN MATEO, SANTA CLARA, ALAMEDA AND
CONTRA COSTA COUNTIES

John R Freeman, Consulting Engineer
Providence, R. I

K R Kennison del

July 8, 1912

SCOPE OF THE INVESTIGATIONS ALREADY MADE AND DESCRIPTION IN MORE DETAIL OF THE STRUCTURES PROPOSED.

(57) In the preceding pages, in course of meeting the request of the Secretary of the Interior for specific information upon the use proposed by the city of the Hetch Hetchy and Lake Eleanor valleys, so full an outline of the proposed works has been given that but little need be added. The plans and profiles presented in the preceding pages show the general scheme as fully as practicable on drawings of that scale.

Probable Increase in Population

(58) A report upon additional water supply commonly begins with a discussion of the probable increase of population. This matter is set forth in the diagram on the preceding page together with some of the data from which the probable future rate of increase is deduced on the most conservative basis that can be reasonably adopted. For example, it assumes only 30 per cent increase per decade for the next twenty years, where actual increase was about 47 per cent in the past decade, in spite of the great fire, and the recent school census shows 5 per cent per year increase for the past two years.

The conclusion is that a population of two millions will be surely reached between 40 and 50 years hence in San Francisco and the other communities bordering San Francisco Bay as far around as Richmond, and that at some time near the end of the present century the population of Greater San Francisco will reach three millions.

It is possible that the three million mark may be reached, or four hundred million gallons of water daily be needed only half a century hence. The rate depends upon the wisdom and vigor with which San Franciscans seize their opportunity. I have not ventured to draw the optimistic population line, nor is this necessary in order to show that the Hetch Hetchy, Eleanor and Cherry sources should all be conserved to the utmost for the future domestic supply of the greater city.

The history of many commercial cities shows that under the conditions of the past half century growth has gone on in geometric progression. The time must come in the history of almost any city when the geometric ratio will decrease because of the land having become occupied to a density that repels growth rather than invites it, or because of the commercial opportunities which support population having ceased to expand, but it is plain that the conditions which tend to stagnation are a long way off in the case of San Francisco.

The prospect for rapid and continuous growth of the entire San Francisco district was never brighter than it is today, and several new causes are now coming into action which seem to foreshadow for at least twenty years to come a more rapid growth than the San Francisco district has had in the past.

Some of these important causes are:

Special Cause for Rapid Growth at San Francisco

(59) First, the approaching opening of the Panama Canal.

Second, the present general tendency to a subdivision of the great individual holdings of land, the present strong movement toward dividing the old wheat fields of the great valley into small irrigated farms and the reclamation of vast areas of swamp lands bordering the lower Sacramento and San Joaquin Rivers by dikes and drainage. These swamp lands are of surpassing fertility. It is stated by those who have given this subject the most careful study that nearly two million acres in the great Central California valley, with climate equal to the finest in the world, can be brought under irrigation by the conservation of flood waters of the mountain streams, which now waste to the sea. All of this great valley is commercially tributary to the cities of Greater San Francisco, and these cities must grow to meet the commercial needs of this increased rural population. Canned fruits and canned asparagus grown in this region are today shipped all over the United States and to Europe, and with the opening of the canal there appears to be no limit to the markets for the products of intensive farming on nearly a hundred thousand acres bordering San Francisco Bay and upon more than a million acres in the great valley.

A third reason for growth is found in the great awakening in the Orient which tends to broader interchange of products between the United States, China and other Eastern countries. The natural commercial center for this is found in San Francisco.

Along with other growth, there will doubtless come some moderate increase in manufacturing, particularly to supply local needs, but it is questionable if this kind of growth will be large. While thoughtful men have doubts about it being advantageous to the civic welfare to multiply a factory population here, the attractions of climate, food and high prevailing rate of wages and the zeal of steamship agents may bring it faster than desired.

Last, but not least, among the causes which promise future growth is an awakening in civic pride and an appreciation of their remarkable opportunities, throughout the communities of Greater San Francisco.

Considering the above potentialities in their relation to San Francisco, and having regard also to the actual rate of growth achieved by various other commercial cities subsequent to attaining the present population of San Francisco, the line of growth which I have projected upon the accompanying population chart may be regarded as extremely conservative.

It assumes that for each of the two next decades the per cent of increase will be two-thirds that of the past decade, and that in the following decades the rate of increase will be smaller, finally tapering down to 10 per cent, and less, toward the close of the century. This rate of growth ignores all such phenomenal per cent of increase as has come to Los Angeles, Vancouver, and other Pacific Coast cities in recent years, and it also ignores the retarding effect of the great conflagration of 1906, on the line of increase which we project.

Remembering the pre-eminent advantage of San Francisco's location and that here is found the only first-class harbor for more than a thousand miles up and down the coast and that this harbor is without a superior in the world, also leads irresistibly to the conclusion that the populations of two millions and three millions are certain to arrive and that the only doubtful element in the discussion is, how soon?

Confirmation by Other Estimates of Population

(60) Professor Marx has partially completed a very comprehensive study of the probable future growth in the various municipal subdivisions, the notes of which are to be placed on file with the Advisory Board of Army Engineers. His studies, based on the density of population in the various urban, suburban and rural communities, indicate that there will be no undue crowding from lack of territory attractive for residential and manufacturing purposes within the century. A summary of his conclusions both as to population and the quantity of water that they will probably demand is shown in the accompanying table. It will be noted that he estimates a probable demand of 441 million gallons daily at the end of the century.

(61) Mr. Herman Schussler, for many years Chief Engineer of the Spring Valley Water Company, has had occasion to study the question of increase on the San Francisco Peninsula with great care and his projection of the curve of growth for San Francisco only, reaches 1,100,000 in the year 1950, and it doubles the present population within the present limits of San Francisco, only about twenty-five years hence.

TABLE SHOWING PROBABLE FUTURE DEMANDS IN THE PROPOSED METROPOLITAN WATER DISTRICT AROUND THE WEST, SOUTH AND EAST SHORES OF SAN FRANCISCO BAY.

Estimated by C. D. Marx.

COUNTY.	Total area available for future population (acres).	Present population (1910).	Probable future density of population. Persons per acre at end of century.	Estimated future population (at end of this century).	Probable future city consumption of water. Gallons per capita daily.	Total future city consumption (million gals daily).	Probable ultimate irrigated acreage.	Probable future irrigation consumption (million gals. per day).	Probable total future demand (million gals. per day for cities and irrigation).
San Francisco—									*
City and County	30,000	417,000	40	1,200,000	130	156	—	—	156
San Mateo County—									
Colma to Belmont	13,000	17,200	15	205,000	130	26	—	—	26
Belmont to Palo Alto	14,000	7,800	8	112,000	130	15	—	—	15
Santa Clara County—									
Suburban	57,000	44,000	8	456,000	130	59	—	—	59
Rural	93,000	34,000	4	372,000	75	28	59,000	59	87
Alameda County and Contra Costa County—									
Suburban	73,000	249,000	15	1,095,000	130	142	—	—	142
Rural	48,000	4,000	36	192,000	75	15	36,000	36	51
	328,000	773,000	—	3,632,000	—	441	95,000	95	540

*Depth of irrigation per year estimated at 1.13 feet for Santa Clara County, as per U. S. Bureau of Agriculture.
Depth of irrigation per year estimated at 1.25 feet for Contra Costa and Alameda counties.

Increase in Use of Water Per Capita

(62) The quantity of water actually used per capita is found to increase from year to year in substantially all growing cities in the United States and is showing a similar, altho slower, rate of increase in most European cities. This comes naturally with higher standards of comfort, with more bathtubs, more water fixtures in the dwellings, and in most American cities this rate of increase has far outrun the expectations of twenty years ago. Even when a meter is installed on every tap, soon after the immediate drop, the curve of per capita consumption again begins to rise, and so soon as the water supply of a city is put on the rational basis of sale only by meter, there is no reason why the city should not encourage the most liberal use, particularly if it very properly adjusts its schedule of rates so as to make this a source of income which can be applied to the embellishment of the city.

There is not one of the necessities of life purchased, which costs so little in proportion to its real value as even the most expensive water supplies and there is no more beneficent luxury than a bounteous supply of water for house, lawn and garden.

After considering the remarkably small per capita use in San Francisco today in comparison with other cities similarly situated and even with those in regions of far more abundant rainfall, which small use it is hard to explain even by the cool summers, the warm winters, and the fog, I cannot believe that this relatively low per capita use will always continue, and there is much reason for expecting that as the population spreads out into the suburban homes, helped thereto by some such suburban railway system as those, for example, now found in Los Angeles and Boston, and by the tunnels thru the hills to the south which it now appears certain will soon be constructed, there will be a marked increase in the use for watering lawns, flower gardens and kitchen gardens and this liberal use should be encouraged.

As one today walks the streets of the residential districts, well-watered lawns and flower gardens are much less in evidence than in Los Angeles or Denver, and in the region of large suburban estates south of the city and county line the water for irrigation of lawns, gardens and cemeteries is pumped from the deep gravels by private plants and does not appear in the statistics. San Francisco is a city of high wages and liberal expenditure for the comforts of life, where each number that goes to make up the census returns stands for much more in the way of expenditure for clothes, food, electric light and liberal use of water than in a city where the population is mainly composed of factory operatives, working for small wages.

The writer having had occasion to study this question of future per capita increase in relation to the water supplies of Boston, New York, Baltimore and other cities, cannot regard it as prudent to estimate on a smaller supply for the San Francisco of, say, fifty years hence, than from 125 to 150 gallons per capita per day, altho by that time substantially every service is metered.

This would give for the year 1950, if the population is then two millions and the consumption 125 gallons per capita, a total draft of 250 million gallons daily and at the end of the century with a draft of 150 gallons per capita would call for a supply of 450 million gallons daily. And as already stated, it is quite possible that the two and a half or three million population needing 400 millions of gallons of additional water may arrive only fifty years hence.

CONSUMPTION OF WATER IN VARIOUS CITIES OF UNITED STATES.

Name of City.	Daily consumption per capita, gallons.	For year.
Denver	213	1911
Pasadena	127	1911
Los Angeles (metered)	130	1910
Cincinnati	127	1911
Salt Lake City	243	1912
Philadelphia	210	1911
Colorado Springs	202	1911
San Diego	104	1912
Cleveland (metered)	104	1911
Washington, D. C.	178	1911
Baltimore	115	1911
Portland, Ore.	83-86	1910-11
Boston	130	1910
Milwaukee	111.9	1911
St. Louis	118	1911
New York (Manhattan and Bronx)	120	1910
Chicago	230	1909
Buffalo	322	1906
Oakland and adjacent 80 from People's Water Co., 30 from wells.	114	1910
San Francisco 85 from Spring Valley Water Co., 13 from wells, and 2 from Golden Gate Park Waterworks.	100	1910

The Peculiar Water Supply Needs of the San Francisco District

(63) A city surrounded by a region that is semi-arid or has an uncertain amount of annual rainfall, like San Francisco or Los Angeles, presents far more serious problems in providing for the future than any found in the Eastern or Central cities of the United States.

For example, in Eastern cities the need for great storage to tide over one year, or two, or even three successive years of small rainfall is far less than at San Francisco. Moreover, in the Eastern cities when an additional water supply is needed the city can go out and secure by means of a willing sale or by purchase under eminent domain, water from some river used to supply water power to a factory, and simply pay the cost of substitute steam power; but in an arid land to thus take water which is already used in irrigation or intensive farming, would leave a desert.

A few years ago Los Angeles awoke with a shock, to find that its GROWTH MUST STOP UNLESS MORE WATER COULD BE OBTAINED from some distant source, and that to take this water from local irrigated farms and gardens was impracticable to a degree that had never been before realized.

The Los Angeles problem and its solution furnishes by far the best analogy to the present San Francisco problem that can anywhere be found, and the same reasons which justified Los Angeles in obtaining control of 273 million gallons daily at a time when its population was only about 275,000, justify the San Francisco metropolitan district with three times that population, in now making absolutely certain of its future control of a supply of 400 million or 500 million gallons daily of the very softest and purest water that can be provided.

Like Los Angeles, San Francisco may prudently now provide a supply that will be ample, so far as can now be seen, for the city's growth during a hundred years to come, and San Francisco may also wisely follow Los Angeles in avoiding unnecessary waste of capital by SO PLANNING ITS WORKS THAT THE SURPLUS CAPACITY OF A GREAT MASONRY AQUEDUCT AND TUNNEL SYSTEM, BUILT TO ACCOMMODATE THE DISTANT FUTURE'S GROWTH MAY BE IMMEDIATELY USEFUL in bringing down water in volume sufficient for the encouragement of intesive farming close to the city, until such time as these farm lands become further subdivided into dwelling lots. It was found in some of the Los Angeles studies that the quantity of water required for an acre of intensive farming and market gardening, was about the same as would be used upon the same ground after this had been subdivided into ordinary suburban dwelling house property, and the irrigation changed to sprinkling of lawns, flower gardens and kitchen gardens.

The Yield of the Present Sources

(64) In planning to meet the demands of the distant future, the amount that can be obtained from the sources now in use must be included, also whatever amount is available from the sources owned by the Spring Valley Company and the People's Water Company not yet put into use, so far as this can be estimated with accuracy, also the Union Water Company sources or others.

(65) There must be some deduction for sources that will have to be abandoned here as they have been in other communities as population encroaches, for example, on the catchment area of Lake Merced.

(66) There is a possibility also that the underground sources around the edge of the salt water where, fed by the slow percolation seaward of water falling on the ground between the shore and the crest line of the hills only a few miles back, may become impaired by over-pumping and the infiltration of salt or brackish water as they have in some of the Brooklyn districts. The data now in course of collection at my request, by Mr. Dockweiler, indicates that the plane of saturation is already being pumped below sea level over large areas. If so, just as when a bank reserve is thoughtlessly overdrawn, a day of reckoning must surely come. The ground water sources all around San Francisco Bay will naturally be devoted more and more to irrigation and manufacturing as time goes on. This is the common experience. Such use has already begun and is actively increasing all around the nearly level plain bordering San Francisco Bay. The factory needing water for industrial purposes can take more chances on over-pumping and the drawing in of salt water than can the municipality supplying water for drinking and steam generation; and as a matter of law and procedure it will probably be found impossible to define any channels for the percolating waters such as would prevent future establishments located anywhere around the bay from sinking wells and pumping these wells all they like. This will surely detract from the supply available for domestic purposes.

(67) With reference to the Niles Cone region. I have had called to my attention a printed copy of a report made by a special committee of the Merchants' Exchange of Oakland on December 5, 1905, relative to the injury alleged caused by the diversion of the waters of Alameda Creek from Niles Cone and I have been informed that the Spring Valley Company was prevented from withdrawing waters from lands which it had purchased near the Bay shore at Ravenswood on which it had sunk deep wells which it soon quit pumping because of injury found or expected to occur to the sources used for the supply of communities in the vicinity of Palo Alto; and that in recent decisions the courts have plainly stated the rule that while a farmer or manufacturer could pump as deeply as he liked for

water to be used on his own premises, although it might lower the local water table below the bottom of his neighbor's well, he could not be permitted to thus pump water to be taken away in pipes to supply some other locality.

A precise determination of the quantity of water suitable for domestic supply that may be depended upon in the long future from the Bay Shore gravels, is thus an extremely difficult matter to determine. It is hard to tell how fast this great underground reservoir is becoming emptied, or how soon a back flow of salt or brackish water will be sucked in with the present great increase of pumping and deepening of draft from year to year.

Present and Future Quantity

(68) For obtaining a rough idea of the future
yield of the present sources we may note that
the Spring Valley Company from its peninsula sources now supplies not far from. . . .
. . . . .20 to 23 mil. gals. day
From its underground sources at Sunol and
Pleasanton not far from. . . . . 15 to 17 mil. gals. day
The Peoples Water Company supplies from its
Lake Chabot system and from its wells in
the Bay Shore gravels a total of. . . . . . 20 mil. gals. day
a present total of about. . . . . 60 mil. gals. day

The above comprises all furnished by the principal water supply corporations, but all over the districts are various small supplies obtained by pumping from wells driven into pervious substrata, mostly of limited capacity.

The reports of Mr. J. H. Dockweiler and of Prof. Marx (see paragraphs (b), (d), (e) following), go into this matter very fully, particularly that of Mr. Dockweiler, and may be referred to for further information.

In brief, it may be said that the quantities of water available from such sources are limited and apparently will all be needed for local use in the near future.

Some additional water can without doubt be secured without material injury to the farmers of the Niles Cone by building the Calaveras, San Antonio and Valle dams, but just how much I am as yet unable to determine and the amount appears to depend in part upon legal considerations. I am led to believe it certain that in the long run the aggregate yield of good water from all sources now in use, notwithstanding new dams be built upstream from Lake Chabot and new reservoirs created at Antonio and Valle will become decreased rather than increased.

When due allowance is made for the future increased use of the local ground-water sources in the Bay shore gravels for irrigation by pumping, as is already being done on the Niles Cone, with much increase from year to year, and for pollution of Lake Merced and for some present wells being made brackish by over-pumping, it appears certain that the future supply which must be brought into this district from a distance should be fully 400 million gallons daily, and if 500 million gallons daily is available in the upper Tuolumne River above the dam sites now proposed the city should make certain of securing this quantity against future needs.

Fortunately we find proof that this requirement can be met from the surplus run-off of Hetch Hetchy, Eleanor and Cherry throughout the dryest years ever yet known.

New Studies Upon Yield of Present Sources

(69) In order to make the most definite answer possible to some of the questions raised in the preceding paragraphs, several investigations have been in progress under my advice and suggestion during the past year. This work was of such a complicated character that after conference it was subdivided and the parts assigned to several experts familiar with the local conditions.

(a) Beginning nearest San Francisco and proceeding around the bay, the estimation of the quantity available in the future from the sources on the western slope of the peninsula, comprising principally San Gregorio and Pescadero Creeks, was assigned to Mr. C. E. Grunsky. This has been nearly completed.

(b) The investigation of the amount at present derived from the various sources (chiefly ground water) south of the San Francisco county line; also the problem of estimating the additional quantity that might be derived from these sources in future and the extent to which they would probably be drawn upon for agricultural and domestic supply, was assigned to Professor Marx. Work on this was interrupted but sufficient for the present needs has been collected and will be filed August 1.

(c) An investigation of the yield of the Alameda Creek and the various Livermore Valley sources tributary to the Spring Valley Company's intake at Sunol, with particular reference to the extent to which additional water could be derived from them in future, was assigned to Mr. Cyril Williams, Jr.

This has been substantially completed. A preliminary copy has been given to the Spring Valley Water Company. In final form this will be filed on August 1.

In this connection I desire to record my appreciation of the courtesy of the officials of the Spring Valley Water Company in rendering to me and to those working with me for the city the opportunity to examine their records and I desire to acknowledge the promptness with which they have supplied the data that I have asked for.

(d) A determination of the quantity at present derived from the sources controlled by the People's Water Company, for the supply of Berkeley, Alameda, Oakland and the various smaller adjacent communities; also the problem of the present and future dependable yield that could be derived by pumping wells driven deeply into the gravel strata easterly from the shore of San Francisco Bay, was assigned to Mr. J. H. Dockweiler. The report on this was filed July 15.

(e) Mr. Dockweiler was also requested to obtain any reliable information for showing any progressive lowering of the plane of saturation, under the agricultural districts of the Niles Cone. This will be filed on August 1. An abstract of his conclusions is attached hereto in Appendix No. 5.

Progress in Studying Present Sources

(70) A recomputation of the Spring Valley Company's estimates of discharge of Calaveras and Alameda Creeks has been in progress for some weeks past under Prof. Charles Gilman Hyde, with the collaboration of Prof. C. D. Marx and Mr. C. E. Grunsky in the effort to obtain, if possible, greater accuracy. No good reason appears why these gaugings could not have been made accurate from the start in December, 1889, but they were taken under conditions of shallow irregular channels, drowned weirs and uncertain gauge points and too infrequent observation in times of flood, and then computed by a formula designed for ideal conditions. It was plain that the few years of the Calaveras record from half the watershed did not show a reasonable relation to the Sunol and Niles records from the whole watershed, nor to the few years of apparently careful measurements made further upstream on the Calaveras catchment by Mr. Edwin S. Duryea, Jr. The U. S. Geological Survey years ago had criticised the record.

On the disclosure of these facts by the report of Mr. Cyril Williams, Jr., I recommended that the record be re-examined in the hope of obtaining greater precision in the discharge measurements.

I regret that the results so far found hardly justify the effort and that tests on a model one-twentieth the actual size recently made for the Spring Valley Company, results of which were very kindly communicated to the city's investigators, are not conclusive as to the retarding effect of the rough rocky bed, the underbrush and the strong flood eddies induced by the upstream bend which give cross currents over the weir, and all absorb energy tending to lessen its discharge.

Therefore, although it is my personal belief that the record as it stands is too large, I am disposed to accept it at face value rather than counsel expenditure of more time and expense on this particular investigation. Meanwhile the 30 per cent reduction estimated in the U. S. Geological Survey publication (W. S. No. 81), may be taken as a standoff for the larger flows indicated by the small model, and whichever set of values within this range is accepted will not in my judgment affect to a material extent the conclusion as to the date when the city must seek a new source for reasons that are set forth later.

(71) In Appendix No. 4 I attach a few photographic views which exhibit the unfavorable conditions for an accurate measurement of this discharge and discuss the conditions more at length in order to emphasize the fact that the estimates of the discharge of Alameda Creek rest upon an uncertain basis and that one must discount the doubtful quantities when planning so important a matter as water supply.

Investigations Confirm Early Need of Large New Supply

Each of the above investigations has already progressed far enough to indicate that their results will not change the conclusions that have been previously stated, to wit: That after making due allowance for the future yield of all of the near-by sources, there will have to be brought to the district from some source at or beyond the San Joaquin River and before the close of the century, an additional supply of at least 400 million gallons daily.

I am led to believe that these reports, particularly those by Mr. Dockweiler and Mr. Williams, together with facts that I have gathered independently, demonstrate beyond a doubt, that neither the Spring Valley Water Company nor the People's Water Company has reserves of so great an extent as its officers had confidently believed and have claimed in many of their published statements. Stating substantially the same fact in another way, there is so much of vagueness and uncertainty in their data, so much of hope, so little of reliable, dependable fact as to yield, particularly of the subterranean sources, that the cities must have the benefit of the doubts in matters so vital as domestic water supply.

My personal review of the various data upon yield of the Alameda sources, is substantially completed, but held open for some additional information promised soon and will be submitted to the Advisory Board of Army Engineers on August 1st.

Investigation of the Irrigation Needs Turlock and Modesto Districts

(72) In order to satisfy any doubts as to the quantity that the irrigation districts might be able to put to beneficial use under a more intensive agricultural development or by an increase in the carrying capacity of their canals or by extending their respective areas to the broadest possible limits, a very painstaking investigation, already mentioned, has been carried

on during the past year by Mr. J. H. Dockweiler, Consulting Engineer, and a corps of assistants, the results of which are fully set forth in a volume of about 300 pages, placed on file with the Advisory Board of Army Engineers, appointed by authority of the President to assist the Secretary of the Interior in this investigation.

These investigations make it plain that the districts now comprise substantially all of the arable land lying between the shores of the Stanislaus River on the north and the Merced River on the South, the rough foot-hill country on the east and the swamp lands of the San Joaquin River on the west, and that they thus contain broad areas that naturally should have looked to the Stanislaus and the Merced River for their irrigation supply and that there is no important area of irrigable land remaining which should naturally look to the upper Tuolumne River.

The Actual Use Found Smaller Than Recorded Priorities

(73) It is found that the greatest volume of water ever yet diverted, regardless of beneficial use, is much smaller than the recorded priorities, and that the use of this water has been excessive and in much of the territory so excessive as to tend to permanently injure the land so that drainage works for pumping off the surplus water are already being planned. It is found that the Modesto Irrigation District has already constructed a reservoir along its canals by which it is enabled to accumulate and store water from its priority on days and seasons when this is not needed for agriculture and that the capacity of this reservoir is capable of much further increase at moderate cost. It is found that the Turlock Irrigation District has similar reservoirs planned. In brief, the result is to show that the proposed diversion by the city of all that it may in future require even up to 500 million gallons daily, would not injure these irrigation districts and need not interfere with their priorities in the slightest degree. Water meters and other gauging devices can be easily provided and maintained by which the release of the lawful priority can at all times be simply adjusted.

City's Storage Sometimes Helpful to Irrigators

(74) On the other hand, the city could often be of great assistance to these districts in seasons when the spring flow of the Tuolumne River is small by reason of scant storage of water in form of snow in the high mountains, by releasing some moderate quantity of water from its storage held over from a previous year of bountiful flow. This could be done with prudence, often during the next thirty or forty years, before the city reaches the need for a second pipe across the San Joaquin Valley.

From the mountain reservoir in which the reserve against drought is held for Denver, such a release of water for farmers has several times been made, greatly to their benefit, but without charge or price, lest a servitude might be imposed that might prove of injury to the city's need at some future time after its consumption of water for domestic purposes has increased.

Additional Supply That the Spring Valley Water Company Could Deliver

(75) Among the properties owned by the Spring Valley Water Company and held to be available for development for supplying future demands of the city, I am led to believe that the only one now of importance permitting delay in going to the mountains is Alameda Creek, which has already been drawn on to the extent of about seventeen million gallons per day, and which it is confidently believed by the former Chief Engineer of the Spring Valley Company could be made to yield a total of about 100 million gallons per day additional.

Several engineers have tried to figure out from very scant data just how much water these 623 square miles above the Sunol dam could be made to yield.

The elaborately worked results are speculative, and one can reach quite as reliable an estimate by simple common-sense methods as by many pages of deduction from data which are exceedingly scant and uncertain in all respects save that there is available a tolerably reliable record of actual daily gaugings of the discharge at the outlet of the valley in the Niles Canyon, which discharge in state of nature varies from almost zero to a mighty flood.

The uncertainty in the estimates of quantity available to the city comes from the wide range of this flow of water through the Niles Canyon, and from difference of opinion about how much of the great floods of 1892-3 could have been put into storage and slowly drawn off five or ten years later during the years of small rainfall from 1897 to 1902; Mr. Schussler and some others apparently reckoning (most absurdly, it seems to me) that by soaking these floods into a large bed of low-pumped gravel they could be almost wholly conserved and saved for the city's use.

The Spring Valley Company's Gaugings

(76) The Spring Valley Company for 23 years past has maintained a series of daily gaugings of the quantity flowing from above its dams in the Niles Canyon. The quantity year by year for most of the term is in a record that has been sworn to in court by Mr. Schussler in 1906. It is also given in modified form and lessened by correction of supposed errors in the report on the water resources of California (Paper 81), published by the U. S. Geological Survey prepared by Mr. J. B. Lippincott. In the early years its gaugings of the great

rush of water in time of flood were particularly crude, and in recent years and up to the present time they fall far short of what is desirable in such an important stream. Nevertheless, they are vastly better than no stream gaugings at all, and better than making the most elaborate deduction from conjectural distributions of the rainfall in this region of peculiar topography and peculiar rainfall and then guessing at the per cent. of it which might be saved.

DISCHARGE OF ALAMEDA CREEK AT NILES OR SUNOL AS COMPUTED BY THE SPRING VALLEY WATER CO. Seasonal year Nov. 1 to Oct. 30 until 1904, thence from July 1 to June 30. (The first year's record includes only 11 months.) Quantities in million gallons.

Year.	Total.	Mean Daily.	Year.	Total.	Mean Daily.
1889-90	156,148	427.	1900-01	32,102	87.7
1890-91	35,125	96.2	1901-02	19,717	59.3
1891-92	19,051	52.2	1902-03	23,500	64.4
1892-93	102,676	281.	1903-04	36,731	100.7
1893-94	55,155	151.	1904-05	20,254	55.4
1894-95	81,127	224.	1905-06	63,164	173.0
1895-96	37,232	115.	1906-07	102,917	282.
1896-97	63,472	174.	1907-08	21,189	58.
1897-98	3,612*	10.2	1908-09	83,989	230.
1898-99	24,849	68.1	1909-10	33,949	97.
1899-00	18,158	49.7	1910-11	74,852	210.

*Corrected for misplaced decimal:

Average for 19 years, 1889-1908, 131.5 million gallons daily.
Average driest year, 1887-1888, 10.2 million gallons daily.
Average driest 2 years, 1887-1889, 39.2 million gallons daily.
Average driest 3 years, 1887-1890, 43. million gallons daily.
Average driest 4 years, 1887-1891, 54. million gallons daily.
Average driest 6 years, 1887-1893, 56.6 million gallons daily.
Average driest 8 years, 1887-1895, 62. million gallons daily.

The official records of these daily gaugings form the basis of the estimates by the former Chief Engineer of the Spring Valley Company and by most of the other engineers, including myself, and like Mr. Schussler and others I have finally taken the record at face value, although I believe it gives too large a flow for reasons which I have stated on a previous page, paragraph (70), and with more detail in Appendix No. 4.

For conserving these flood waters Mr. Schussler plans to build the three great storage reservoirs at Calaveras, Antonio and Valle, which have a little less than half of the whole catchment area above them, and for the additional storage needful he relies upon the pore space in the vast beds of gravel, cubic miles in extent, which fill the Livermore Valley, as explained by Professor Branner, whose conclusions on the geology I fully accept.

The estimate of Mr. Schussler that about 119 millions a day could be taken hence to San Francisco, in effect assumes to store and take away substantially every gallon that would have flowed down the Niles Canyon during a period of about twenty years, a theoretic result which is most utterly impossible in practice for several reasons.

Some Optimistic Estimates of the Spring Valley Company's Reserves for Future Growth

(77) This Spring Valley estimate simply sums up every gallon that the records show to have been discharged down the Niles Canyon past the Company's dam during the nineteen years (which was 918 billion gallons), and dividing this by nineteen years and by 365 days per year,

finds an average of. . . . . 132.2 mil. gals. daily.

From this he deducts as probable waste in the wet season, 1888-89, an amount which, if spread over the nineteen years, lessens the daily average by. . . . . 7.2 mil. gals. daily,

but makes no deduction whatever for waste during the following 18 years. For evaporation from the three proposed reservoirs, Calaveras, Antonio and Valle, he deducts . . . . 5.1 mil. gals. daily.

The remainder is his estimate of the amount available to the city. . . . . 120. mil. gals. daily,

of which amount there is now being diverted about . . . . 17. mil. gals. daily.

This method of computation thus shows an additional diversion possible of. . . . 103. mil. gals. daily.

But the data used in the above method of estimation need correction.

Errors in Spring Valley Records of Flow at Niles Canyon

Mr. Williams' review discovered one mistake of a decimal point and certain minor mistakes which lessen the Spring Valley Company's record of Sunol runoff in the driest year by about 14 mil. gals. daily. Taking the evaporation net loss at 50 inches depth, which I believe possible under the California sun and the temperature prevailing at these reservoirs summer and winter, and supposing the reservoirs average three-fourths full, gives an average evaporation loss throughout the year of 8.4 mil. gals. daily, which exceeds Mr. Schussler's estimate by 3.4 mil. gals. daily, so that the corrected quantity, instead of 103, would stand 99 mil. gals. daily, as a corrected Spring Valley Company's estimate of the possible ultimate development of the sources which it owns and holds in reserve to supply the future growth, and if the evaporation loss is taken as large as the records of height, inflow and draft at the Crystal Springs Reservoir appear to demonstrate the figure would be reduced to almost precisely 100 million gallons per day.

(78) Further corrections are presented by J. B. Lippincott in the publication by the United States Geological Survey, entitled California Hydrography, Water Supply Paper No. 81, 1903. His records of flow of Alameda Creek were based primarily on testimony given in the suit of Clough vs. Crystal Springs Water Company, involving diversion rights from Alameda Creek, tried in the autumn of 1901.

In the report referred to Mr. Lippincott states that the large flood measurements previously computed and presented by the Spring Valley Company, contain considerable elements of error, but these measurements which he regarded as erroneous are the same as still used in Mr. Schussler's report. Mr. Lippincott, on behalf of the Geological Survey, corrected the record so far as he could and the following table gives in briefest possible form the correction, which applies principally to the months of large flow and to large depths wasting over the dam. As a whole Mr. Lippincott's corrected quantities for the flood months are only about two-thirds of the quantities given by the Spring Valley Water Company:

TOTAL DISCHARGE FOR THE YEAR.

	S. V. Co.	U. S. G. S.
Dec., 1889, to Oct., 1890, inclusive....	156,148	95,881
Dec., 1890, to Oct., 1891, inclusive....	35,125	26,597
Dec., 1891, to Oct., 1892, inclusive....	19,051	16 946
Dec., 1894, to Oct., 1895, inclusive....	81,827	58,383
Dec., 1895, to Oct., 1896, inclusive....	37,232	27,344
Dec., 1896, to Oct., 1897, inclusive....	63,472	43,357
Dec., 1898, to Oct., 1899, inclusive....	......	......
Dec., 1899, to Oct., 1900, inclusive....	18,158	15,039
	411,013	283,547
Average	58,700	40,500=31% less

This at least indicates that the Spring Valley Company's table of gaugings as presented is a weak foundation on which to build up estimates of the additional quantity of water available in this source for meeting the growth of the city. The records in question were more fresh by ten years when Mr. Lippincott examined them than they are today and the crest of the dam has since been rebuilt and I am told the water height measurer has since died. There were no gauges.

This correction of Mr. Lippincott's very materially lessens the quantity deduced by Mr. Schussler and lessens the computed flow available for diversion to the city in the three-year and eight-year periods noted elsewhere in this report.

I have no positive proof that Mr. Lippincott's correction was precisely correct. My opinion from studying the photographs and measurements and visiting the spot, and from many years' experience with the vagaries of weir measurements and obstructed channels is that there should be some such reduction as that made by Mr. Lippincott.

Subsequent to 1900 the measurements were made over the new Niles dam where they are not subject to the same disturbing conditions and are probably more accurate, but still unreliable in extreme floods.

Deductions for Local Use

(79) But other possible deductions must be made when considering the supply available for San Francisco in future. The local use for the towns of Livermore and Pleasanton and for local factories may be increased. Mr. Schussler makes no allowance for this. How much this town and factory use may be in future is conjectural. Plainly they possess the adverse right.

Of more importance is the probable increase of pumping from the gravels for irrigation and more intensive farming within the Livermore and Pleasanton Valleys. Whatever is thus taken and evaporated in plant growth will not be available to the city. The level valley floor contains upward of 60 square miles, and in addition there are say twenty square miles of foothills probably suitable for agriculture with irrigation. Each square mile irrigated with the minimum depth that we have assumed for Modesto, namely, a water "duty" of two feet of net depth applied to the area farmed would call for

$$\frac{5280 \times 5280 \times 748 \times 2 \text{ ft.}}{365 \text{ days.}} = 1.14 \text{ million gallons daily.}$$

It is easy to see that an awakening to intensive farming might absorb a very large part of the possible annual catchment of the underground gravel reservoir within the Livermore and Pleasanton Valleys. The Soil Survey of the Livermore area, California, published last year in pamphlet form by the U. S. Department of Agriculture, is of interest in showing that much of this soil would be responsive to irrigation.

But apart from all such questions of increased local use, it can be easily shown, as follows, that the accuracy of Mr. Schussler's estimate is impossible.

Impossibility of Conserving All the Alameda Flood Flow

(80) It is mechanically impossible to store all the torrential floods of the year 1892-93, for example, and carry their waters in storage for five to ten years, and slowly deal them out during the dry years from 1897 to 1903, as would be required to keep up Mr. Schussler's estimate of daily outflow. It is impossible to find sufficient storage space either in reservoirs above ground or available in the pore space underground in the gravel beds. On half the total catchment area (fortunately the least prolific half) there are no practical sites for storage reservoirs, and in the matter of underground storage, it is a fact shown by the Company's records that the floods come with such a rush that the gravels at the head of the Livermore

Valley cannot possibly drink the flood water all in. Much of it must necessarily continue to waste over the dam in the Niles Canyon.

Under natural conditions the outflow from these 623 square miles above the Niles Canyon shrinks to almost nothing during August, September and October of the ordinary year, but on the day following a very heavy rain the waste of water comes down thru the Niles Canyon with a rush, and probably it always will.

The records show that after each flood the discharge soon shrinks. A typical case is plotted in the diagram on the opposite page.

The present diversion, which varies from 8 to 17 million gallons daily at different seasons, is secured by draining the sands or gravels of the Sunol Valley and by pumping from the porous sands and gravels at Pleasanton, but there is plainly a limit to this process, and at the Sunol filter gallery, so far as I can learn, the limit has been already reached. For the proposed new territory to be exploited, I find some reason for believing that this limit of underground storage and diversion will be reached when the six millions now pumped at Pleasanton have been duplicated by another pumping station and another line of wells farther up the valley.

Great Storage from Gravel Beds Impracticable

(81) Mr. Schussler, Mr. Mulholland, Mr. Lippincott and others appear to figure out that by first pumping down the water level in the gravels upstream from Pleasanton a storage space can be provided sufficient to absorb and drink down all floods as they pass, and that this subterranean storage could be pumped out and delivered to the city whenever needed. This may look plausible at first view, but I cannot believe it practicable after studying the records and going over the ground. There are three obstacles:

The records show that the water comes with such a rush that it does not and cannot possibly all soak in. Today the gravels at the head of the valley, which is where the greatest and most porous beds all lie, are drained low before the flood season begins. Altho the valley floor looks level to the eye, it is, in fact, sloping at the rate of 20 or 25 feet per mile, so that the upper easterly end of the broad gravel intakes of the Valle and Mocho Creek beds is tipped up some 300 feet above the outlet near Laguna Creek, and a plotting of the Spring Valley Company's daily records shows that long before autumn, whatever storage came into these upper gravel beds during the flood has drained out down to the level of this outlet. This is proved by the low rate of flow in Laguna and Alameda Creeks thru the summer and early autumn. The accompanying plotting of the flow from December, 1906, to June, 1907, is a good illustration of what happens.

Rapid Response to Rain Proves the Limited Storage Capacity

(82) The rapid rise in the flow past the Sunol dam after a heavy rainfall proves the incapacity of the gravel beds at the head of the Livermore Valley to drink in a flood flow beyond certain moderate limits, notwithstanding the mouth of the underground reservoir has become emptied both by natural drainage and by pumping from the gravels at Pleasanton or Livermore.

The geological sections show that by far the greater portion of the level valley floor is covered by a deep, impervious clay cap and the porous intake exists only at the upper end.

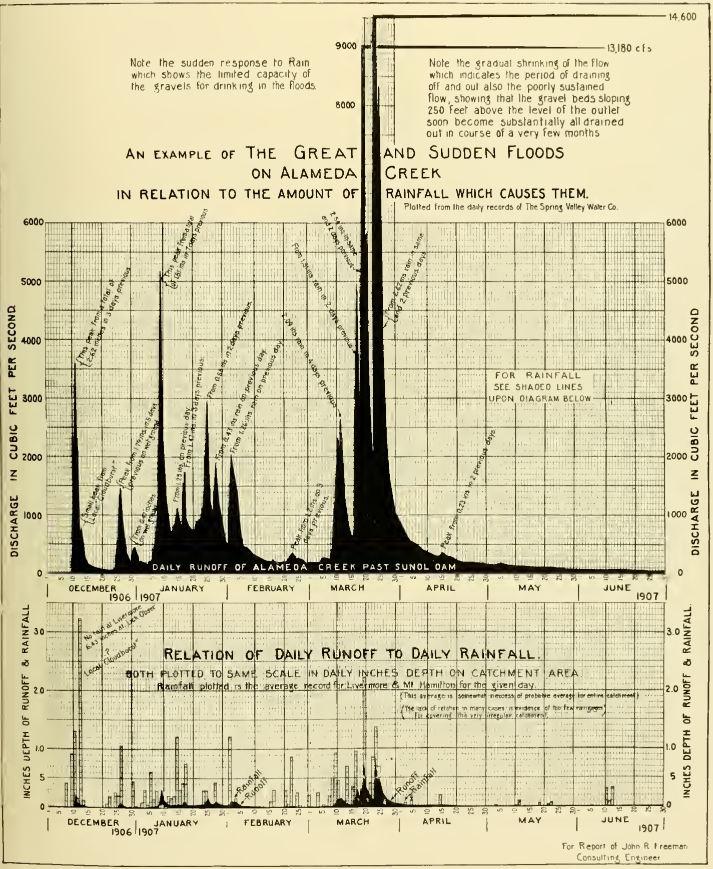
The many records of well borings industriously compiled by Mr. Cyril Williams, Jr., from the log books of the men who have drilled them, prove that the valley is largely filled with impervious material, and that the pervious gravels and sands lie in pockets or kidneys communicating to a certain extent with one another, but with a vast proportion of impervious pore-filled ground, which has no available storage capacity, surrounding the gravel pockets and gravel channels.

I present a few of these sections on the following pages.

It is purely conjectural for one to figure out the extent of this pore-space storage which can be made practically available, and in every winter flood we have proof positive that the rush of water does not soak into the beds of gravel at the head of the Livermore Valley, which were drained out during the preceding summer.

Well Drillers' Logs Under-Estimate Clay Mixed in Gravel

Commonly the log or record of a well driller fails to take proper account of the proportion of fine sand or clay that is mixed in with the coarser material which he classes as gravel. This fine material is largely carried off in suspension in the turbid water poured out from the sand bucket or flushed over the edge of the tub in which he collects his samples. In borings for the Boston and New York water works it is only by special precautions and use of a flocculant that it has been found possible to retain and measure these finer particles.



AN EXAMPLE OF THE GREAT AND SUDDEN FLOODS ON ALAMEDA CREEK IN RELATION TO THE AMOUNT OF RAINFALL WHICH CAUSES THEM.

Plotted from the daily records of The Spring Valley Water Co.

Note the sudden response to Rain which shows the limited capacity of the gravels for drinking in the floods.

Note the gradual shrinking of the flow which indicates the period of draining off and out also the poorly sustained flow, showing that the gravel beds sloping 250 feet above the level of the outlet soon become substantially all drained out in course of a very few months

RELATION OF DAILY RUNOFF TO DAILY RAINFALL.

BOTH PLOTTED TO SAME SCALE IN DAILY INCHES DEPTH ON CATCHMENT AREA

Rainfall plotted is the average record for Livermore & Mt Hamilton for the given day.

(This average is somewhat in excess of probable average for entire catchment)

(The lack of relation in many cases is evidence of too few raingages for covering this very irregular catchment.)

For Report of John R. Freeman
Consulting Engineer

14,600
9000
13,180 c.f.s.
8000
6000
5000
4000
3000
2000
1000
0
DISCHARGE IN CUBIC FEET PER SECOND
This peak from a total of 2.62 inches in 3 days previous
Small peak from Local "Cloudburst"
Peak from 1.79 ins. in 5 days previous on wet ground
From 0.87 inches on wet ground
This peak from a total of 1.51 ins in 7 days previous
From 1.23 ins. on previous day.
From 1.47 ins. in 3 days previous.
From 0.58 ins in 2 days previous
From 0.43 ins rain on previous day
From 1.26 ins rain on previous day
2.09 ins rain in 4 days previous
Peak from 1.2 ins. on 3 days previous
From 1.31 ins rain in 2 days previous
2.54 ins in same and 2 days previous
From 2.62 ins rain in same and 2 previous days
Peak from 0.23 ins in 2 previous days
FOR RAINFALL SEE SHADED LINES UPON DIAGRAM BELOW
DAILY RUNOFF OF ALAMEDA CREEK PAST SUNOL DAM
5
10
15
20
25
30
DECEMBER
1906
1907
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
1907
No rain at Livermore
6.43 inches at Lick Obser
?
Local "Cloudburst"
Rainfall
Runoff
Runoff
Rainfall
3.0
2.0
1.0
.5
0
INCHES DEPTH OF RUNOFF & RAINFALL

The Deep Gravels Probably Largely Impervious

(83) While I do not for a moment question the conclusions of Professor Branner, that a great depression of the bedrock has occurred, more than a thousand feet deep over the area of the Livermore Valley, and that this space has been filled irregularly with gravel, sand and clay, it is, I believe, a matter of common sense that the pore spaces within the deeper parts of this gravel down to the depth that could be profitably pumped, are not available for quick absorption and quick delivery in a way that permits any such development of underground storage as has been figured out by Messrs. Schussler Mulholland, Lippincott and others. The term "gravel" as used by a geologist does not necesasrily mean a porous substance. To him it is still "gravel" after its pores are filled.

Filtering Turbid Water Clogs the Pores

(84) When for more than a thousand years turbid waters have sunk in at the upper end of the valley and have come out filtered and clear at the lower end of the valley beneath the clay cap, such finer particles as caused the turbidity of the water entering this filter must have become lodged in the deep pores, nor can it be urged thoughtfully that the thin skin of silt deposited over the gravel during the retreating stages of a flood and which is perhaps scoured off and washed out to sea by the crest of the next succeeding flood, performs all the act of filtering and that the filter becomes thus automatically cleaned and renewed year by year without clogging the deep gravels, for if any such great proportion of the flood discharge as is supposed by Mr. Schussler and his associates were to be retained in storage beneath the Livermore and Pleasanton plains after there had been a vacancy previously pumped out to receive it, where would this skin of silt be washed to if none of the water reached the sea?

The many logs of borings collected by Mr. Williams prove conclusively that most of the bulk of the valley refill is impervious and that, as any one would expect who has studied the formation of delta cones where clay abounds, these gravels lie in very irregular pockets. Prof. Branner also reaches this conclusion.

A city cannot base its providing for future water supply on matters so largely conjectural as the possibility of storing and promptly reclaiming any large additional amount of these Alameda flood waters underground.

Possibilities of Surface Storage

(85) As previously stated it is possible to build three large surface reservoirs on Calaveras, Antonio and Valle creeks at the lower end of about one-half of the entire catchment area, and this the most prolific half of the 623 square miles. After repeated inspection I regard each of the three dam sites as feasible for dams of almost any height that a mass-curve study of the creek discharge shall show desirable.

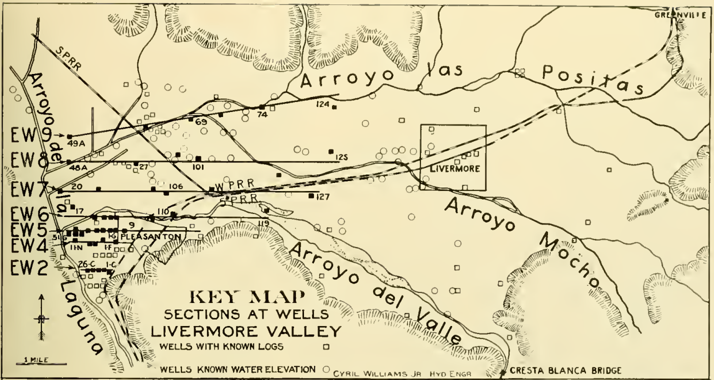
Unfortunately for present purposes, we have no dependable information upon the discharge of either one of these creeks. In spite of its many years of ownership the Spring Valley Company never has kept any good records of rainfall or of continuous run-off gaugings in these valleys. This would have been a simple and inexpensive matter by means of weirs and recording clock stream gauges and clock rain gauges, which need be visited but once a week or once a fortnight.

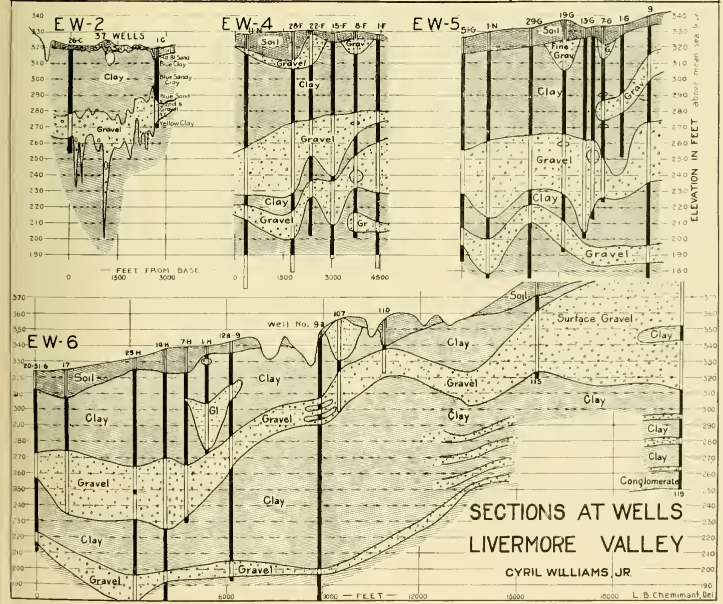
(86) The distribution of the rainfall is so variable and so much affected by the circulation of the air currents over these projecting spurs of the Coast Range that it is largely conjectural what average depth of rain falls in each valley and what percentage of it escapes evaporation and runs down the stream.

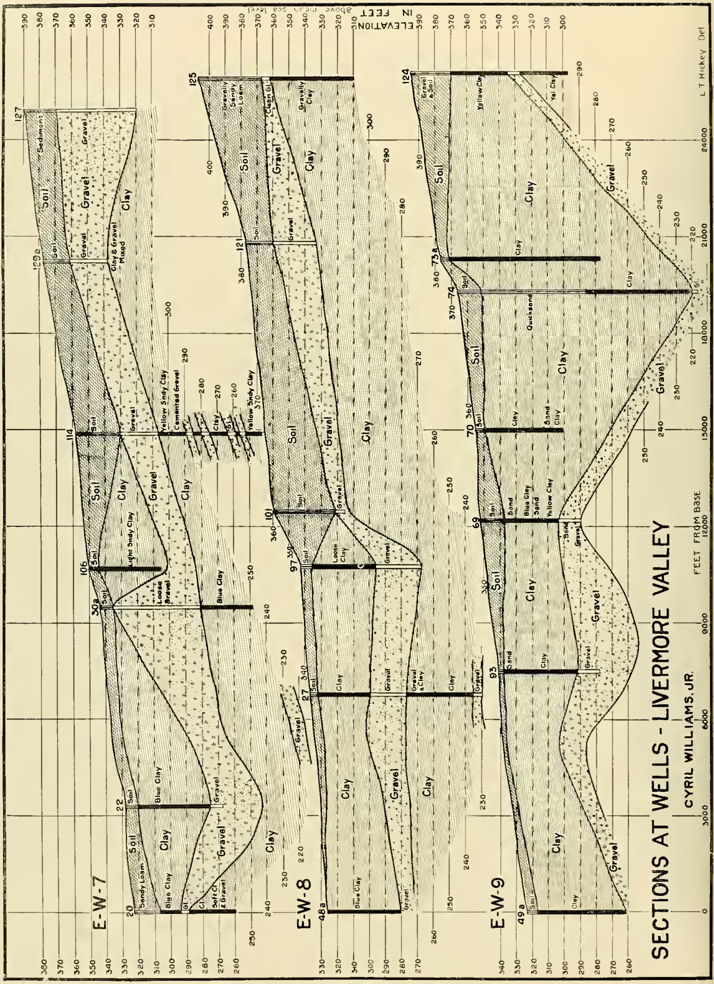
Although there may be artesian water at the north edge of the valley refill from the vast deposits of pliocene gravels shown by Professor Branner's researches, the source of such water must plainly be the rain within the watershed area measured on the topographic maps.

Lack of Run-off Data for Surface Reservoirs

(87) While it is easy to figure out how much the daily delivery would be from a ten-billion gallon reservoir if discharged at a uniform rate during one thousand days, we have no certain data as to how many years would be required to fill it or to refill it, and, for example, we have no means of accurately determining what would be left in the case of the Valle Reservoir after the evaporation losses. How far it will pay to go in building the Antonio and the Valle reservoirs depends on data never yet obtained. In the case of the Calaveras Reservoir there were some crude gaugings kept for a number of years which are plainly erroneous and out of all reasonable proportion to the simultaneous gaugings at Sunol, but disregarding these gaugings it appears so plain from the exposure of this catchment on the slopes of Mt. Hamilton to the vapor-laden winds and from its relatively large area that there is little doubt about the advisability of incurring the expense of building it when its value as a reserve near the city is also taken account of if one may assume, as I do, that the water from the upper 45 square miles will not be taken away. (See page 95.)


KEY MAP
SECTIONS AT WELLS
LIVERMORE VALLEY
WELLS WITH KNOWN LOGS □
WELLS KNOWN WATER ELEVATION ○
CYRIL WILLIAMS JR HYD ENGR
CRESTA BLANCA BRIDGE
1 MILE
Arroyo del la Laguna
Arroyo las Positas
Arroyo Mocho
Arroyo del Valle
LIVERMORE
PLEASANTON
GREENVILLE
SPRR
W.P.R.R.
S.P.R.R.
EW9
EW8
EW7
EW6
EW5
EW4
EW2
49A
48A
27
20
17
9
51G
1-G
1-N
1-F
26-C
1-C
69
74
124
101
125
106
127
110
119


EW-2
37 WELLS
26-C
1C
Soil
Yld Bl Sand
Blue Clay
Blue Sandy Clay
Blue Sand
Sand & Gravel
Yellow Clay
Clay
Gravel
FEET FROM BASE
0
1500
3000
EW-4
11-N
28F
22-F
15-F
8-F
1-F
Soil
Grav
Gravel
Clay
Gravel
Clay
Gravel
Gr
4500
EW-5
51-G
1-N
29G
19G
13G
7-G
1-G
9
Soil
Fine Grav
Clay
Grav
Gravel
Clay
Gravel
ELEVATION IN FEET above mean sea level
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
EW-6
20-51-G
17
25H
14H
7H
1-H
12a-9
Well No. 93
107
110
115
119
Soil
Clay
Gl
Gravel
Clay
Gravel
Clay
Gravel
Surface Gravel
Clay
Gravel
Clay
Clay
Clay
Clay
Conglomerate
370
360
350
6000
9000
FEET
12000
15000
18000
SECTIONS AT WELLS
LIVERMORE VALLEY
CYRIL WILLIAMS JR.
L. B. Chemimant, Del.



SECTIONS AT WELLS - LIVERMORE VALLEY

CYRIL WILLIAMS, JR.

Some Long Periods of Small Alameda Flow

(88) Returning again to the Spring Valley Company's records of the total run-off through the Niles Canyon in its pipes and down the stream bed, and taking these figures at face value, although I believe them too large, we note that the total average run-off measured during the year 1897-98 was for the seasonal year only 10.1 mil. gals. daily,
from which there would have to be deducted for evaporation had the three reservoirs been in use and three-fourths full, 8 or possible . 10 mil. gals. daily,
leaving practically nothing to flow down the stream . . . . 0 mil. gals. daily.

The 17 million gallons taken then must come from the underground storage.

If every gallon had been held back during three consecutive years 1897 to 1900, and allowing as before, 8 million gallons daily for evaporation losses, would give from the entire 623 square miles only . . . . 35 mil. gals. daily.

Again, taking the eight consecutive years from 1897 to 1905, if every gallon shown by the Spring Valley Company's records to have passed its Sunol gatehouse and dam during this period could have been stored and dealt out at a uniform rate, the total constant quantity without deduction for either evaporation or increased local use, would have been only . . . . 62 mil. gals. daily,
but evaporation must be taken account of, which would reduce the average to . . . . . . 54 mil. gals. daily,
and beyond this increased local use must surely be allowed, for it is inconceivable that it would have been practicable to have held back every gallon during these eight years by any practicable means.

(89) I am inclined to believe that if every gallon could be thus held back and diverted from passing down the Niles Cone during so long a period as eight consecutive years, the farmers of the Niles Cone would have trouble. This might be quite as much due to their own excessive pumping in years of small rainfall, but doubtless they would attribute any shortage to the holding back of water for the city, and bitter controversies and petitions for injunction against the diversion of everything from above the canyon to San Francisco would probably follow. Therefore the question of how far can additional diversion from the Livermore Valley and Alameda Creek be relied upon for supplying the growth of the city is quite as much for lawyers as for engineers.

(90) Much complaint and controversy and litigation has been had in the past over the diversions, already made by the Spring Valley Company, of water which otherwise would have flowed out through the canyon and have contributed to replenishing the water pumped from the saturated sands and gravels of the Niles Cone.

Present and Future Depletion of Ground Water in Niles Cone

(91) After reviewing the data thus far collected by Mr. Dockweiler as to the height of the ground water over various sections of the Niles Cone, I am led to believe that the farmers are mistaken about very large depletion or lowering of the water table having already occurred as the result of the Spring Valley Company's diversion, but I am confident that if the diversion were to be so complete as assumed in the estimates of Mr. Schussler and those who agree substantially with him in methods and results of computing the yield, there would be a serious depletion.

A visit to this region makes it plain that the local use of water for irrigation is very rapidly increasing, and that the region will doubtless before many years need more water than it can possibly receive both from its rainfall, averaging 18 inches, and from whatever floods might come under natural conditions down the Niles Canyon and soak into the broad area of gravel near the mouth of the canyon and thence spread out beneath the clay cap and replenish the saturated sands from which the farmers' irrigation pumps draw.

At present only a fraction of all this area has been brought under intensive farming and irrigation, and the present pumps thus have the opportunity to collect water naturally appurtenant to a much larger area than is possessed by the owners of the wells, and perhaps the same is true on the Hayward Cone, and on other of the level lands around the head of the Bay, which have no such supplies from the back country as comes down Alameda Creek to the Niles Cone. A study of the geology and a review of the lay of the land proves that this water cannot come from a distance.

Source of the Ground Water

(92) It is plain beyond all doubt or question that the only source of these underground waters is the rainfall on the ground above, supplemented by whatever water comes down creeks from the back country during the rainy season. The Niles Cone is more fortunate than the other broad areas of arable land around the head of San Francisco Bay in having its direct rainfall supplemented by the periodic flushes of water from the 623 square miles drained by Alameda Creek.

700 GALLONS PER MINUTE PUMPED FROM 8-INCH WELL.

Equivalent to one million gallons in 24 hours, if kept up.
Only 25 million gallons pumped during season, which is equivalent to a uniform draft of only 0.068 million gallons per 24 hours.

A WELL ON THE BELL RANCH, DECOTO, CAL.

About four miles northwesterly from apex of Niles Cone. One hundred and eighty-five acres in garden truck.

IRRIGATING TOMATOES, BELL RANCH, DECOTO, CAL.

One hundred and eighty-five acres in truck products.

FIFTY-ACRE STRAWBERRY FARM, NILES.

Established in 1911.

IRRIGATING SCENE, CALIFORNIA NURSERY COMPANY, NILES.

Six hundred acres near apex of the underflow, uses over 150 million gallons annually, about one-third of which comes from Spring Valley pipes.

IRRIGATING A FIFTY-ACRE STRAWBERRY FIELD NEAR NILES.

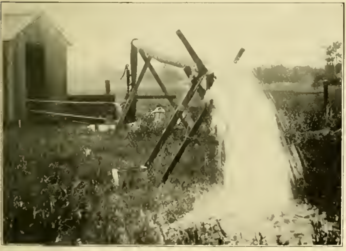
Gross valuue of crop said to be over $50,000 annually.

IRRIGATING ALFALFA, GREGORY RANCH, DECOTO, CAL.

About four miles northwesterly from apex of Niles Cone.

AT THE PUMPING PLANT OF THE NILES STRAWBERRY FARM.

Fifteen-horsepower electric motor; 700 gallons per minute.



THE BART BROWN WELL, ARDEN, NEAR NEWARK, ON THE SOUTHWESTERN MARGIN OF THE NILES CONE.

Pumping ground water from well for the irrigation of an alfalfa field.

IRRIGATING YOUNG APRICOT TREES, CALIFORNIA NURSERY, NEAR NILES.

July 1, 1912.

The Niles Cone Needs This Water for Irrigation

(93) I am told there is over 40,000 acres of arable land suitable for intensive farming, truck gardening and nurseries within the area known as the Niles Cone. If two feet "duty" or net depth of water per year over the surface of the land is required, which is the minimum we have assumed for Turlock and Modesto under a less intensive kind of farming, this would call for 40,000 acres x 43,560 square feet x 2 feet x 7.5 gallons=26 billion gallons per year, chiefly in the growing months. Some of this would reappear as seepage, less than one-third. Allow for this and spread the remainder over 365 days, as in water supply estimates, it will average nearly 47 million gallons per day required in addition to the rain which falls upon its own area. This makes it plain that for the fullest development the district will need to have its saturated substrata replenished from the natural flow down the Niles Canyon. In the litigation of Clough vs. Spring Valley it appears to have been proven that the gravels in the creek bed at the head of the cone could drink in at no higher rate than 30 million gallons daily, flows beyond this escaping over the clay cap to the sea. The creek flows above the 30 million gallon rate for only part of the year, and goes nearly dry after midsummer. So with no diversion whatever to San Francisco there would ultimately be a shortage for the farmers on the cone.

These farmers now have their irrigation reservoir underground, the more progressive farmers are already drawing from it, and irrigation by pumping is increasing. On one large tract irrigation wells are being put down one to every 25 acres. This underground reservoir will surely become injured by the infiltration of salt water if what is pumped out from year to year exceeds the quantity that is put in.

The process of lowering ground water is slow when dealing with an area the size of the Niles Cone, and some time must elapse before the irrigable land will be all equipped with pumps, and whether the extension of pump draft for San Francisco at Pleasanton and Livermore by the Spring Valley Company or its successor in ownership, plus the further abstraction and diversion from the Calaveras, Antonio and Valle storage reservoirs, will cause injury to underground reservoir of the Niles Cone that will become sufficiently obvious to afford proof in court before the statute of limitations would protect the corporation in its diversion of a larger draft of water from above Sunol, it is hard to tell. As to the latter, I would call attention to Appendix No. 6, which the City Attorney has prepared at my request.

Right to Percolating Water

(94) I am told that there is the highest legal authority against depriving a land owner to his injury of the percolating waters which have been provided by nature and have slowly permeated the ground beneath his growing crops. That the water coming from the outflush of the Niles Canyon does percolate beneath the Niles Cone appears to be proved by the shape of the water contours found by plotting the well heights, which show plainly a general slope from the outlet of the canyon toward the sea.

It is now well understood that the slope of a water table produces flow in the percolating waters and that percolating water runs down hill and in the direction of the steepest slope of the water table, very much as upon the surface.

Ground Water Studies Needed

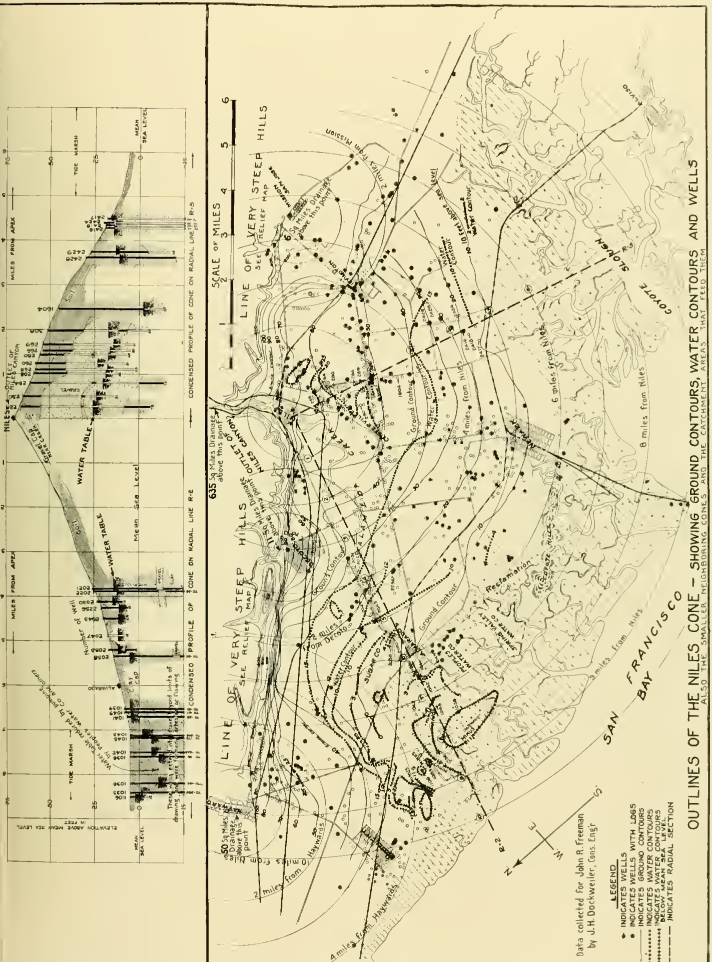
(95) Plainly, it is important to consider all of these questions in connection with the future supply of both the San Francisco District and the Oakland District, which is supplied from wells at the outer edge of the Niles Cone.

In order to answer the question precisely as to what are the additional water resources of the Bay shore gravels would require one or two years of observation similar to those recently made by the city of New York on Long Island, in which a great number of small driven well pipes, two inches in diameter, were put down along the public highways, cross-sectioning the area in various directions, and by means of these the natural ground water level should be observed week by week for one or two years. One observer equipped with a bicycle can observe a great number of wells in the course of a day.

A most painstaking canvass has been made during the past three months for such information as could be found from existing wells, the results of which will be set forth in a report by Mr. Dockweiler, to be presented to the Advisory Board of Army Engineers on August 1st.

From my study of the advance sheets of this report on the Niles Cone, in connection with that on the People's Water Company sources and such other information as I have been able to collect, I am led to believe that taking a long look into the future, the quantity of water suitable for domestic supply, particularly to Oakland and the neighboring cities on the east side of the Bay, will grow smaller rather than larger, and that the additional quantity available to San Francisco from the Spring Valley sources cannot be reckoned prudently at more than 15 or 20 million gallons daily. I doubt if it will pay to do more than build the Calaveras Reservoir before proceeding with the construction toward the Hetch Hetchy, stopping perhaps a few years on the way at Antonio and Valle.

The Calaveras Reservoir can conserve the flood waters which escape over the Niles Cone to the sea at times when the run-off of Alameda Creek is above 30 million gallons daily.



OUTLINES OF THE NILES CONE — SHOWING GROUND CONTOURS, WATER CONTOURS AND WELLS

ALSO THE SMALLER NEIGHBORING CONES AND THE CATCHMENT AREAS THAT FEED THEM

Data collected for John R. Freeman by J. H. Dockweiler, Cons. Engr

Adverse Rights on Headwaters of Alameda Creek

(96) All the estimates of Alameda yield which I have seen presented by the Spring Valley Company fail to make any deduction for the possible utilization of water rights to the several creeks on the slope of Mt. Hamilton which enter the Calaveras and Valle reservoir sites, the water rights of which creeks with catchments aggregating 45 square miles, are understood to be in the adverse possession of the Union Water Company, the Bay Cities Company or the United Properties Company, with a view to their being utilized for the supply of the cities on the east side of the Bay. Personally, I doubt if the parties owning the water rights filed on these sources can find it profitable to build the dams and divert their waters because of large expense, small capacity and remoteness, therefore I judge they will probably continue available as a part of the Alameda source and tributary to the Calaveras reservoir.

That the owners have a different view is indicated by the following letter forwarded me while revising the printers' proof sheets.

THE UNITED PROPERTIES COMPANY OF CALIFORNIA.
SAN FRANCISCO, July 27, 1912.

Mr. J. H. Dockweiler, Consulting Engineer, Grant Building, San Francisco, Cal.

My Dear Sir:—In connection with the report on the water supply of the cities around the Bay of San Francisco, which I understand is now being made by John R. Freeman, Consulting Engineer, assisted by yourself, rumors have reached me that unfriendly interests are making representations that the Mt. Hamilton supply of the United Properties Company, formerly known as the Mt. Hamilton supply of the Bay Cities Water Company, is a dead project and without any present value.

I wish to deny all such reports and to say that this project, which contemplates the water supply of the cities on the east side of San Francisco Bay from Isabel Creek, Smith Creek, Bonita Creek and the Arroyo Valle, all on Mt. Hamilton, is still in full force; that the water rights have been and are now being kept up, in accordance with the laws of the State of California; that this Company has actual ownership of all such lands as are necessary for the full development of the water supply of these streams, and that we consider the project as valuable, if not more so, than we did formerly, and, further, that we fully expect to develop these water rights and properties and to carry out our plan of furnishing water to the cities on the east side of the Bay of San Francisco in the near future.

Very truly yours,
(Signed) WILLIAM S. TEVIS,
First Vice-President.

While it is for lawyers and courts to settle these questions of water rights, the engineer can form a judgment from engineering and business conditions, and I still believe these waters will probably always continue tributary to the Calaveras reservoir.

Other Spring Valley Sources

(97) As to the other water resources of the Spring Valley Company, I am led to believe they are not of sufficient importance to have any important bearing on the date of seeking a distant source like the Hetch Hetchy. Among these are the Ravenswood wells and the large areas of ground overlying porous gravels, bought years ago by the Spring Valley Company, on the southeast margins of the Bay. I am credibly informed that years ago when the company began pumping these wells an injurious effect was noted on wells and water supplies taken from the gravel near Palo Alto, so much so that suits and injunctions were threatened and the pumping was stopped and has never been resumed.

The decision of the Supreme Court of California quoted in Appendix No. 6, appears to cover this situation fully, and to forbid that this source be reckoned available to the city of San Francisco.

(98) As to the Pescadero and San Gregorio Creeks. These supplies are manifestly so small and the dam sites so expensive that I believe they have no bearing on the Hetch Hetchy question. I regard their diversion much as I do the diversion from the 45 square miles on Mt. Hamilton away from Calaveras already discussed.

The gaugings of stream flow of Pescadero and San Gregorio are utterly insufficient to form a dependable basis for estimating the quantity they could supply. The flood waters may come too fast for diversion and storage.

Moreover, they will some day doubtless be needed for the growing communities on Half Moon Bay, which appear geographically entitled to them. The fact that the Spring Valley turned its back on these sources years ago and incurred the large expense of the pipe to Niles and the filler gallery at Sunol appears to confirm this view.

(99) With regard to the large areas owned by the Spring Valley Company near Alvarado, not far from the wells of the People's Water Company, it is plain that these are subject to substantially similar conditions as the wells of the People's Water Company. Moreover, if the Alameda flow were to be restrained above Sunol, the natural supply by infiltration to these wells would soon cease and salt water be drawn in if they were heavily pumped for a long term of years. Altho the lowering of a ground water table along the fringe of the Niles Cone may be slow, it is none the less a certain process, if more be taken out than is put in. (See location, page 95.)

Wherever serious uncertainty exists in data for estimating a source of additional water supply for a city the doubt should be construed in favor of safety. A factory can stop operation when its water supply fails; a city cannot.

Conclusions Regarding Additional Supply From Present Sources

The whole situation as I find it may be summed up in the following simple statements:

(1) The only source of any particular account in providing more water for the future growth of San Francisco, owned by the Spring Valley Water Company, is whatever may now remain available in the Alameda Creek source.

(2) Estimates presented by the Spring Valley Water Company grossly over-estimate the quantity that could possibly be stored and taken from that source, regardless of all the adverse water rights and priorities of other parties.

(3) The legal right to have about 30 million gallons daily of the Alameda water (so far as nature provides it) flow down through the Niles Canyon so that it may sink into the gravels of the Niles Cone for replenishing the underground storage beneath the cone, is apparently paramount and can be invoked to prevent anything like the complete diversion proposed by the Spring Valley Water Company.

(4) Probably in time of floods there remains a surplus from the flow of Calaveras Creek over and above what can be absorbed by the Sunol gravels or the gravels of the Niles Cone, and which will waste into the sea unless conserved by some such reservoir as that proposed on Calaveras Creek.

(5) It is possible, but by no means certain, that additional quantity sufficient to warrant the expense of impounding it can be obtained by building storage reservoirs upon San Antonio and the Arroyo Valle.

(6) It is possible, but by no means certain, that the broad gravel deposits upstream from Pleasanton and Livermore can drink in and store enough of the flow from the various tributaries so that an additional line of wells, equal perhaps in yield to the Pleasanton wells, could be constructed near Pleasanton and Livermore, which being sunk deeply and provided with deep pumps, might supply an additional quantity equal to the present yield at Pleasanton, by exhausting the present accumulations of storage and relying upon the run-off of many wet years to supply the water pumped during a long series of dry years, but the amount that can be thus obtained will remain speculative until demonstrated by some years of use.

As a whole, the additional quantity available from all the sources owned by the Spring Valley Company is probably no more than sufficient to supply the increasing demand until the proposed Hetch Hetchy works could be completed, if begun within the next three years.

For the cities on the east side of San Francisco Bay the additional quantity that can be obtained from near-by sources is also speculative and perhaps may prove insufficient to supply the proper increasing demands of the communities until the Hetch Hetchy works could be built, if begun within three years.

The court decisions presented in Appendix No. 6 also have an important bearing on the question of how much further the People's Water Company can go in diverting percolating water from the edge of the Niles Cone for use in Berkeley for example.

Doubtless some increase could be had by immediately raising Lake Chabot in the manner that I have suggested, and thus conserving substantially all of the flood flow of San Leandro Creek, but this would not be enough to permit delaying the new source very long, and in view of the recent opinions of the California Supreme Court, set forth in Appendix No. 6, and the agricultural needs of the San Leandro Cone and the other cones, there may be some question if it would be permissible to store and divert all the flow of San Leandro, San Pablo, Pinole and other creeks.

It is worthy of note that the People's Water Company has been making its recent extensions from its ground water sources rather than from surface storage, and that the diversion of ground waters and surface waters from the land to which they naturally pertain has taken on a new aspect since the decision of the Supreme Court of California in 1910.

New Daily Gaugings of Run-off Hetch Hetchy, Eleanor, Cherry

(100) The next study in logical sequence was the determination of the run-off from each, the Hetch Hetchy, the Lake Eleanor and the Cherry Creek watersheds.

Actual gaugings of the daily discharge of the Tuolumne River near the Hetch Hetchy dam site were made under the supervision of Mr. Grunsky precedent to his report of 1902, and at the same time gaugings were carried on at Lake Eleanor, but these gaugings covered so brief a period that, of themselves, they did not establish the relation between the annual precipitation and the run-off, nor did they give with sufficient accuracy the percentage of the flow at the Hetch Hetchy and Eleanor dam sites to the flow gauged daily by the U. S. Geological Survey near the Lagrange Dam.

For this reason the City Engineer, Mr. Manson has had a water-gauging party continuously stationed in the Hetch Hetchy Valley for about two years past, another at Lake Eleanor, and similar gaugings have been maintained daily by Mr. Wm. Hammond Hall upon Cherry Creek under an agreement with the City, all in order to make a definite comparison, day by day, of the quantity flowing at the sites proposed for the City's dams with that flowing at the dam of the Turlock and Modesto Irrigation Districts at Lagrange, and thus give positive information upon the quantity of water that would be available to the city at these reservoir sites under the laws of the State of California regarding water rights, and after taking care of all adverse existing water priorities.

In appreciation of the importance of making sure that there was plenty of water both for the city and for the irrigation districts an analysis of these water gaugings was prepared by Mr. M. S. Bartell, C. E., of the City Engineer's office. A second independent study of them has been made by Mr. Cyril Williams, Jr., who made a special search for data to fill gaps in the published records of canal flow at Lagrange, and a further analysis of the gaugings was made at my home office under my personal supervision.

There can be no doubt that the impounding of the floods by a dam or dams of suitable height will give plenty of water for each party concerned. A careful study of the water priorities has been made and is reported in an appendix.

Per Cents of Lagrange Discharge Coming From Upper Catchments

(101) The interesting facts have been brought out that the three watersheds, Eleanor, Cherry and Hetch Hetchy, discharge their principal flood flow at different dates,—Lake Eleanor comes earliest, commonly in April, because of its average watershed being at lower altitude, where snows melt earliest and where rain falls from weather conditions which produce snow on the higher mountains; Cherry comes next, in May and June, because of having a relatively larger area upon the slope of the high mountains and the Hetch Hetchy Valley comes latest of all, in June and July and with sustained flow until August, because of its catchment area spreading out toward the upper end in fan shape with the outer margin following the crest line of the highest mountains. (See map on page 24.)

By means of these daily gaugings at these dam sites, ratios of the monthly and daily flow at each of the city's three reservoir sites to the monthly or daily flow at the Lagrange gauging station of the U. S. Geological Survey have been worked out, from which ratios it is now possible to utilize the records of the U. S. Geological Survey made during the past seventeen years at Lagrange, for determining the quantity available for storage or diversion month by month at the city's reservoir sites.

AVERAGE PER CENT OF TOTAL DISCHARGE OF TUOLUMNE RIVER AT LAGRANGE WHICH IS FOUND TO COME FROM THE WATERSHED OF EACH OF THE FOLLOWING NAMED TRIBUTARIES UPSTREAM FROM THE CITY'S PROPOSED DAM SITES.

	Hetch Hetchy Watershed	Lake Eleanor Watershed	Cherry Watershed	Total
September	55.2%	4.3%	19.2%	78.7%
October	44.0%	5.1%	12.7%	61.8%
November	38.1%	8.0%	17.2%	63.3%
December	22.1%	10.9%	13.3%	46.3%
January	18.0%	7.8%	9.5%	35.3%
February	19.8%	9.6%	10.5%	39.9%
March	18.9%	9.4%	7.8%	36.1%
April	†26.7%	12.0%	13.3%	52.0%
May	†40.3%*	9.4%	16.8%	66.5%
June	47.0%	8.0%	16.1%	71.1%
July	58.7%	5.9%	14.8%	79.4%
August	52.6%	5.0%	7.9%	65.5%

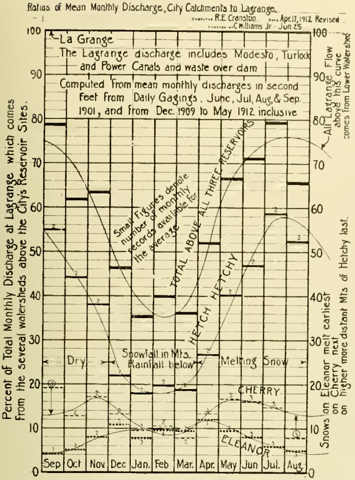
(From gaugings of 1901, 1910, 1911, 1912, to May inclusive).

*Partly estimated (Falls Creek record of 1912 not yet available) but estimated from Cherry.

†Tuolumne River discharge for 1912 subject to revision by U. S. G. S.

These per cents will be changed more or less by a few more years of observation. But they are fairly dependable, one of the years of observation having been of large precipitation and the other below the normal.

The relation of these percentages month by month is shown in the diagram on following page.



Actual Gaugings vs. Estimates From Rainfall

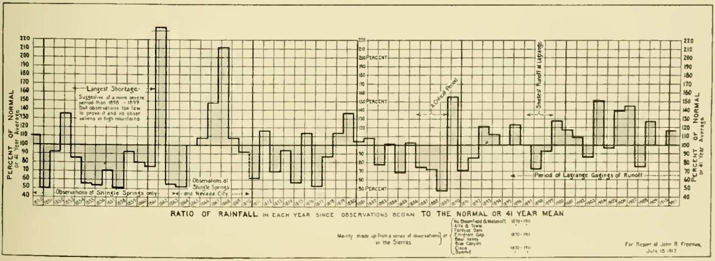
(102) We have today much better data on the run-off from the Hetch Hetchy, Eleanor and Cherry catchments than was available to Mr. Grunsky ten years ago and this more accurate data leads to larger estimates of the quantity of water available to the city.

Prior to the gaugings of the flow at each damsite, described in the preceding paragraphs, estimates of the probable flow had to be made from assumptions regarding the precipitation over their respective watersheds, derived from rain and snowfall observed elsewhere, followed by assuming the probable portion or per cent of this rainfall that would appear as run-off, being guided in those assumptions by percentages measured from catchments extending lower down the mountains.

Estimates thus made often serve a most useful purpose in the absence of something better, but they are at best far less reliable than actual gaugings, particularly under the conditions found in this high mountain watershed and they are so coming to be regarded by the Hydrographic Branch of the United States Geological Survey.

As to the estimates based on rainfall in the present case we have no good information about the average depth of snow and rainfall over and around these high catchments. There never has yet been a single raingauge observed for any noteworthy period in a situation that is fairly representative of the most prolific portion of these watersheds in the high Sierras, where no one lives to observe the depth of the winter precipitation. Raingauges all through the mountains, in order to be conveniently observed, have had to be set at the lower altitudes and in "wind-gaps" or valleys where precipitation differs from that on the mountain side and the gaugings of run-off the year round also have been made at lower altitudes where they have averaged the poorer with the better catchment. Here we have the best part of the catchment segregated above our dams.

There never was a raingauge set anywhere within either the Hetch Hetchy, the Eleanor or the Cherry catchment until



those recently established by the city near its camps; and the two years of runoff as gauged when computed in the form of average depth over the catchment shows up so nearly the same as the depth of rainfall as to indicate that the raingauges do not represent the average precipitation.

Any estimate made by projecting southward isohyetal lines worked out from raingauges at high altitudes in the Northern Sierras and raingauges at lower altitudes in about the same latitude with Hetch Hetchy, are also misleading because substantially all of the raingauges from which these curves are derived have been located near human habitation in the valleys under conditions less favorable for precipitating the moisture than those which are presented on the mountain ridges.

Comparison of Extreme Dry Periods

(103) The comparison in diagram at bottom of page 99 of total yearly rainfall for a long term of years at six different stations indicates that since rainfall records began in California, 62 years ago, there have been two other periods of small rainfall—one of which was possibly longer and more severe than that of 1897-8, but these records are suggestive rather than conclusive as to conditions that prevailed in the high Sierras.

Larger Precipitation in the High Sierras

(104) Not only is the annual amount of snow and rainfall larger at these high altitudes than has been previously supposed, but also the ratio of run-off to rainfall must certainly be larger than farther down the slope of the mountains. This results primarily from the very small depth of soil cover, leaf mould and verdure overlying the bare granite rocks, which, as I noted in my inspection of the catchment area, immediately about Vernon Lake presents conditions closely analogous to the relation of rainfall to runoff presented by a slate roof. In other words, a rapid rainfall will nearly all run off.

The second important difference in condition as compared with catchments at lower altitudes is the smaller evaporation due to lower temperature, particularly at night, and the fact that for more than a third of the year all precipitation upstream from our damsites passes instantly into storage in the form of snow and ice, from which, of course, there is some evaporation. The lessened evaporation by night as compared with that by day at these high altitudes is also an important factor.

In the course of investigations of which I had charge some six or seven years ago, in connection with making preliminary plans for the water power development on the Feather River, since constructed by the Great Western Power Company, I found it necessary to establish a first-class meteorological observatory in the catchment and established this at Prattville, near the Big Meadows, at an altitude of 4,310 feet. This was maintained for the better part of a year. It contained the best of instruments for recording temperature, humidity, wind movement, evaporation, barometer, etc., and the recording instruments were systematically checked by skilled scientific observers. The recording hygrometer, for example, for a long time was checked at morning, noon and night by a sling psychrometer. We found that with the rapid fall of temperature in the clear air at this altitude, soon after sundown the relative humidity rose to the dew point because of the fall in temperature, and simultaneous observations of our floating water tank showed that evaporation practically ceased during the night.

The smaller transpiration and evaporation of moisture in these high altitudes, because of the lessened verdure, the smaller sponge-like evaporating surfaces of humus and leaf mould, must all have a noteworthy effect in increasing the proportion of runoff from precipitation.

The studies of the yield of the Hetch Hetchy, Eleanor and Cherry catchments that we are now able to present, cover two years and more, of daily gaugings of the runoff, and are so very much more dependable than the partly conjectural estimates based upon rainfalls and runoffs measured at lower altitudes and in situations not representative of these watersheds which formed the bases of the earlier Hetch Hetchy estimates that I have relied upon them and discarded estimates of yield based on the conjectural amount of rainfall, save as a rough check.

New Studies of the Lagrange Gaugings

(105) For seventeen years past the United States Geological Survey has maintained daily gaugings of the Tuolumne River at Lagrange at a point near the diversion to the irrigating canals of the Modesto and Turlock Districts, the discharge in each of these canals, also that in the neighboring canal of the Lagrange Water & Power Canal, being included in the total run-off, day by day.

We have carefully gone over the published records, supplied the missing data from the original notebooks and thus obtained a record of the discharge of the river at Lagrange month by month for the period of seventeen years, which fortunately includes one of the most severe periods of scant rainfall known since the settlement of California.

Determination of Upper Tuolumne Run-off Prior to Direct Gauging

(106) Applying to these records at Lagrange the percentages of the foregoing table, we have a very good basis for estimating the monthly flow, month by month, at each of the city's three dam sites.

This has been done for the whole period of seventeen years since the Lagrange gaugings began, and we have thereby obtained the best possible approximation to the run-off month by month during this time at Hetch Hetchy, Eleanor and Cherry.

Subtracting the Priorities

(107) Having computed these quantities by the above method, the quantity that came month by month from that portion of the watershed downstream from the city's proposed dam sites is found by simple subtraction, and obviously on days when the yield of the lower watershed was more than sufficient to supply the Lagrange priorities, the city would have been free to shut the gates at its dams and there store or divert all of the water that came in from the three upper watersheds.

Conversely, on days when the total flow at Lagrange was less than or equal to the priorities of 2410 second-feet, nothing could be stored by the city at either Hetchy, Eleanor or Cherry dams. (The release of irrigation priorities can obviously be made just below power house No. 1 instead of at the dams.)

There are many intermediate days in the year when the flow from the total watershed is more than sufficient for the priorities, while that from the lower watershed is insufficient, and on such days the city might be compelled to release sufficient to make up the full priority.

In this way the amount available to the city month by month for the whole period of seventeen years has been computed and the results summed up in the form of a mass curve or summation hydrograph. The following diagrams, K, L, M, show the relation of the flow available to the city to that needed for the priorities.

Comparison of Rain Gauge With River Gaugings

In proof of the statements on the preceding page, that the precipitation averages much larger on the high mountain side than at such rain gauge stations as of necessity have had to be selected, we have now the results of nearly three years' comparison of the rain gauges set at the city's camp near the outlet of Lake Eleanor, at 4,650 feet above sea level, constantly under the very competent charge of J. O. Todd, C. E., and nearly two years of observations of a rain gauge at the city's camp in the Hetch Hetchy Valley, at 3,530 feet above sea level. From personal inspection I noted that both were standard U. S. Weather Bureau gauges, 8 inches in diameter, and properly set with top about 3 feet above the ground, in an open space where the wind effect would probably be small. And I was told the snow was measured at a sheltered open spot shown in the woods and a section carefully cut out and melted after each storm.

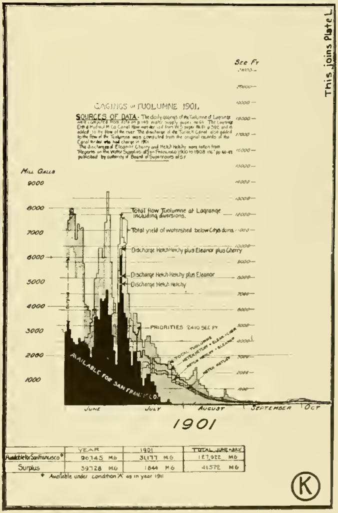
I believe that both this rain gauging and this water gauging were exceptionally accurate.

The records show:	Total inches depth of precipitation at outlet of valley.	Total inches depth of run-off gauged from whole catchment.	Approx. per cent of precipitation which ran off.
Lake Eleanor, seasonal year 1909-10. . .	42.13	45.86	108
Lake Eleanor, seasonal year 1910-11. . .	59.26	66.25	112
Hetch Hetchy, seasonal year 1910-11. . .	46.86	50.88	109

These data are presented in greater detail on page 105.

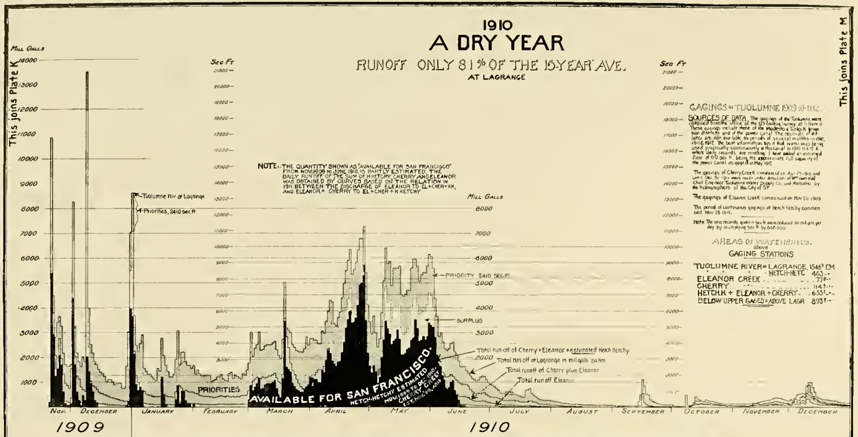
The fact that depth of run-off exceeded the depth of rain at outlet simply proves that the average precipitation for the catchment as a whole was far greater than at this comparatively sheltered spot of lower altitude at the outlet of the valley.

I have noted somewhat similar results from gaugings at the head of the South Yuba River near Lake Spaulding, in the Sierras a hundred miles north.



	YEAR	1901	TOTAL JUNE-JULY
Available for San Francisco*	96145 MG	31177 MG	127,922 MG
Surplus	39728 MG	1844 MG	41572 MG

* Available under condition 'A' as in year 1911



1910
A DRY YEAR
RUNOFF ONLY 81% OF THE 15-YEAR AVE.
AT LAGRANGE

NOTE:- THE QUANTITY SHOWN AS "AVAILABLE FOR SAN FRANCISCO" FROM NOV 1909 to JUNE 1910, IS PARTLY ESTIMATED. THE DAILY RUN OFF OF THE SUM OF H HETCHY CHERRY AND ELEANOR WAS OBTAINED BY CURVES BASED ON THE RELATION IN 1911 BETWEEN THE DISCHARGE OF ELEANOR TO EL+CHER+HH, AND ELEANOR + CHERRY TO EL+CHER+H HETCHY

GAGINGS of TUOLUMNE 1909-10-11-12

SOURCES OF DATA. The gagings of the Tuolumne were obtained from the office of the US Geolog Survey at S Franco. These gagings include those of the Modesto & Turlock Irrigation districts and of the power Canal. The records of the latter are non available for periods of several months in 1910, 1911 & 1912. The best information was that water was being used practically continuously in this Canal in 1910 11 & 12 & where daily records are missing I have added an assumed flow of 60 sec ft, being the approximate full capacity of the power Canal as gaged in May 1912

The gagings of Cherry Creek commenced on Apr 13 1910 and until Dec 31 1911 were made under direction of Wm Ham Hall Chief Engineer Tuolumne Water Supply Co. and thereafter by the hydrographers of the City of SF

The gagings of Eleanor Creek commenced on Nov 20 1909

The period of continuous gagings at Hetch Hetchy commenced Nov 29 1910.

Note The orig records given in sec ft were reduced to mil gals per day by multiplying Sec ft by 646000

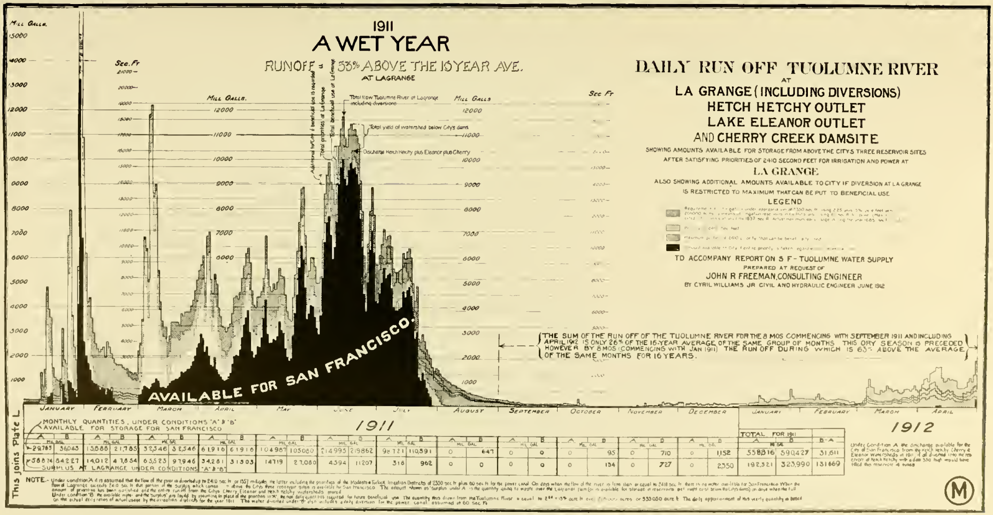
AREAS OF WATERSHEDS.
above
GAGING STATIONS

TUOLUMNE RIVER at LAGRANGE. 1548? □M
" " " HETCH-HETC 463 " "
ELEANOR CREEK .... 77? " "
CHERRY " .... 114? " "
HETCH.H. + ELEANOR + CHERRY ... 655? " "
BELOW UPPER GAGES & ABOVE LAGR 893? " "

Note.- The discharge records for Eleanor are continuous from Nov 1909 to May 1912. These of Cherry commence in April 1910, and of Hetch Hetchy in Nov 1910. The profile therefore from Nov 1909 to Nov 1910, does not show the full amount available for S F as estimated wholly from [illegible]

	ESTIMATED RUNOFF UPPER TUOLUMNE RIVER, AVAILABLE FOR SAN FRANCISCO; YEAR 1910 also SURPLUS.							TOTAL FOR YEAR 1910
Available for San Francisco	13,237 MG	135 MG	29551 MG	79150 MG	76,701 MG	20,267 MG	0	0 No water available for San Francisco	219,041 MG
Surplus	5,765 "	0 "	859 "	10,570 "	26,629 "	3238 "	0	0 from June 18th to end of December	47,061 "

Note; The 'Available' water and the 'Surplus' shown in above profile, for 1910, are determined as under conditions "A" in 1911



MONTHLY QUANTITIES, UNDER CONDITIONS "A" & "B" AVAILABLE FOR STORAGE FOR SAN FRANCISCO

	January A	January B	February A	February B	March A	March B	April A	April B	May A	May B	June A	June B	July A	July B	August A	August B	September A	September B	October A	October B	November A	November B	December A	December B	Total for 1911 A	Total for 1911 B	B-A
	Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		Mil. Gal.		
Available for storage	29,785	36,043	15,888	21,785	32,546	32,546	61,916	61,916	104,987	105,060	214,995	219,862	98,721	110,591	0	647	0	0	0	95	0	710	0	1,152	558,816	590,427	31,611
SURPLUS AT LAGRANGE UNDER CONDITIONS "A" & "B"	58,874	84,227	14,012	41,854	65,523	97,946	34,281	31,503	14,719	27,080	4,594	11,207	316	962	0	0	0	0	0	134	0	727	0	2,550	192,321	323,990	131,669

Under Condition A the discharge available for the City of San Francisco from the Hetch Hetchy, Cherry & Eleanor Watersheds in 1911, if all diverted into the reservoir at Hetch Hetchy with a dam 330 high would have filled this reservoir 4 times.

NOTE.- Under condition "A" it is assumed that the flow of the river is diverted up to 2410 sec ft or 1557 mil. gals., the latter including the priorities of the Modesto & Turlock Irrigation Districts of 2350 sec ft plus 60 sec ft for the power canal. On days when the flow of the river is less than or equal to 2410 sec ft there is no water available for San Francisco. When the flow at Lagrange exceeds 2410 sec ft that portion of the surplus which comes in above the City's three reservoir sites is available for San Francisco. The amount shown as "Surplus" under A is the quantity going to waste over the Lagrange dam (or is available for storage in reservoirs yet might exist below the City's dams) on days when the full amount of priorities has been satisfied and the entire runoff from the City's Cherry, Eleanor and Hetch Hetchy watersheds stored.
Under condition "B" the available water and the "surplus" are found by assuming in place of the priorities in "A" the max. daily quantities required for future beneficial use. The quantity thus drawn from the Tuolumne River is equal to 2 [illegible] acre ft over [illegible] acres or 533,050 acre ft. The daily apportionment of this yearly quantity is based on the actual daily ratios of actual usage by the irrigation districts for the year 1911. The water diverted under "B" also includes a daily diversion for the power canal assumed at 60 Sec Ft.

Mass Curves

(108) A copy of the mass curves during the period of greatest drought is given in outline on the accompanying drawings on pages 106 and 107.

In computing these mass curves, which are simply a continuous summing up of the total monthly run-off, very much as if we were computing the accumulating content month by month of a reservoir of unlimited capacity with no outflow, a curve is plotted which serves as the basis for determining the greatest rate of yield possible day by day under a continuous uniform draft, the various rates of draft being represented by straight lines tangent to the mass curve and drawn at slopes corresponding to the daily rate of draft. The difference between the straight line and the mass curve at any point serves to show the depletion of the reservoir that would have occurred upon the given date and the intersection of the straight line with the curve at the end of the period of depletion serves to show when the reservoir will become refilled, beyond which point all is wasted up to the date when the draft line again becomes tangent.

In computing these mass curves it has been assumed that the Hetch Hetchy Reservoir would be built first, and that it made no difference to the irrigation district whether the amount of water which must be released from day to day in order to satisfy their priority was released from the Hetch Hetchy or from one of the other reservoirs, therefore on days when such release is necessary it has been reckoned as first being taken from Cherry so far as that would suffice, and next taken from the flow of Lake Eleanor. This causes the mass curves for Eleanor and Cherry to show a smaller accumulation than otherwise. To avoid complication of the mass diagrams the effect of evaporation has not been plotted. It is found not to affect the final result. There are various compensations which will much more than offset it, which also have not been incorporated.

From these mass curves it will be noted that by means of a dam storing 110 billion gallons there could have been supplied a daily draft of 420 cubic feet per second from the Hetch Hetchy reservoir alone, and that with dams 150 feet in height, storing respectively 37 billion gallons at Eleanor and 18.5 billion gallons at Cherry, these reservoirs could have supplied in addition 137 cubic feet and 69 cubic feet per second, or 400 million gallons daily for all three.

But the dam sites at both Eleanor and Cherry are very unfavorable as to length of dam and quantity and cost of the masonry involved, as is indicated by the diagram on a previous page, showing a comparison of these dam sites. (Page 8.)

Fortunately, it will not be necessary to build dams so high as 150 feet at either Eleanor or Cherry in order to obtain the above quantity, for two reasons:

The Actual Release for Priorities is Smaller Than Theoretic

(109) First, it has been found as a matter of practical experience in the operation of storage dams and irrigation systems that the actual amount which can be retained in storage is materially larger than the theoretic amount. This results from the fact that there are many days in the course of the year, when by reason of railfall or other cause, the irrigation districts can make no use of the quantity which might be claimed under their priority.

I have nad occasion to note this fact in connection with a study of the storage behind the Cheesman Dam, which forms the great reserve of the Denver Union Water Company, in a region where water for irrigation purposes is probably as jealously guarded as anywhere in the United States.

Irrigation Needs Less Than the Priorities Deducted

(110) A second reason why this volume of water can be conserved with lower dams is that the investigation next to be described shows that the irrigation districts have never yet been able to put into beneficial use or to divert through their canals the full quantity of water claimed in their priorities.

A Daily Estimate of Quantity Available to City

(111) To obtain a still more precise estimate of the quantity available to the city, a computation has been made day by day during the period while gaugings were going on both at the dam site and at Lagrange, and the amount determined that would have been available to the city under the most favorable interpretation of the irrigation priorities, estimating these at face value. These results are plotted in the form of the diagrams which follow, which show graphically the large amount that would have been available to the city in each of these years, day by day.

(112) Other mass curves have been prepared under assumptions believed to be more strictly in accordance with the facts and which follow the results of an investigation upon the maximum quantity of water which can be put to beneficial use in the Modesto and Turlock Districts. These show materially larger quantities available to the city and leave little doubt that these three watersheds can be made in the distant future by means of liberal expenditure for storage dams at Eleanor and Cherry, and possibly some smaller dams farther upstream, on Lake Vernon, for example, to give nearly or quite 500 million gallons daily to the city.

The data and results of these computations will be set forth more at length in supplementary reports to be filed with the Board of Army Engineers.

Confirmation of Yields: Hetch Hetchy, Eleanor and Cherry Reservoirs

(113) Because of the great importance of this determination I have had computations wholly independent from those made in my own office, worked up by Mr. Cyril Williams, Jr., after a further painstaking review of data on file in the City Engineer's office. His results fully confirm those already given, and show that about 400 million gallons daily would be available to the city under the most adverse supposition, dams being built to substantially the same ultimate height that I have proposed in this report. His computations will be presented in a report to be placed on file with the Board of Army Engineers on August 1. The earlier computations made by Mr. M. J. Bartel in the City Engineer's office also tend to the same result.

MONTHLY RELATION OF RAINFALL OBSERVED ONLY AT VALLEY OUTLET TO RUN-OFF FROM A HIGH MOUNTAIN CATCHMENT.

The year is divided at September 1st in order to properly account for the fall rains and snowfall of December with the run-off of the following June. The small run-off in August and September proves the small ground storage and that no important quantity from the rainfall is carried over to the following year. All of the following quantities are computed in inches depth over the catchment area.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Year, total.	Ratio.
Eleanor, 1909-10:														
Rain and melted snow........	(0)	0.85	9.10	13.20	8.21	4.04	4.70	1.78	0.16	0.00	0.09	0.00	42.13	
Run-off	(0)	(0)	3.95	5.22	4.19	2.29	7.22	11.21	7.91	3.25	0.53	0.09	45.86	109%
Eleanor, 1910-11:														
Rain and melted snow........	2.05	1.90	1.87	1.92	26.56	5.59	12.50	5.73	0.81	0.33	0.00	0.00	59.26	
Run-off	0.12	0.23	0.43	1.53	6.20	4.04	5.38	10.32	12.90	17.06	7.06	0.96	66.25	112%
Eleanor, 1911-12:														
Rain and melted snow........	0.28	0.61	2.67	3.00	3.96	0.03	7.68	4.47	2.08	0.65	(0)	(0)	25.43	
Run-off	0.18	0.10	0.14	0.18	0.50	0.91	1.70	3.72	9.65	6.84	(1.0)	(0.2)	25.12	99%
Hetch Hetchy, 1910-11:														
Rain and melted snow........	0.00	1.83	1.87	2.10	21.45	3.61	9.89	3.88	1.07	0.34	0.82	0.00	46.86	
Run-off	0.20	0.28	0.22	0.46	2.30	1.28	2.18	4.07	7.85	19.00	11.62	1.42	50.88	108%
Hetch Hetchy, 1911-12:														
Rain and melted snow........	0.39	0.63	1.59	2.59	3.03	0.34	6.73	4.29	2.71	0.58	0.04	(0)	22.92	
Run-off	0.30	0.18	0.16	0.09	0.25	0.31	0.65	1.29	5.88	7.87	1.86	(0.30)	19.14	83%
Portolacca (Hog Ranch), elevation 4,600, 1910-11:														
Rain and run-off	—	—	0.96	1.43	21.13	4.16	9.85	4.40	1.03				Total seven months, 42.96	
Rainfall at Hetch Hetchy, elevation 3,530, same seven months, 43.87														
Cherry Creek, 1909-10:														
Run-off	—	—	—	—	—	—	—	10.11	12.42	5.66	0.77	0.4	—	
Cherry Creek, 1910-11:														
Run-off	0.91	0.54	0.68	1.44	5.32	3.27	3.91	7.73	12.42	25.10	14.13	1.19	76.64	
Cherry Creek, 1911-12:														
Rain and melted snow........	0.10	0.36	2.73	6.17	—	—	—	—	—	—				
Run-off	0.16	0.08	0.19	0.11	0.47	0.58	1.05	2.49	10.94	11.25				

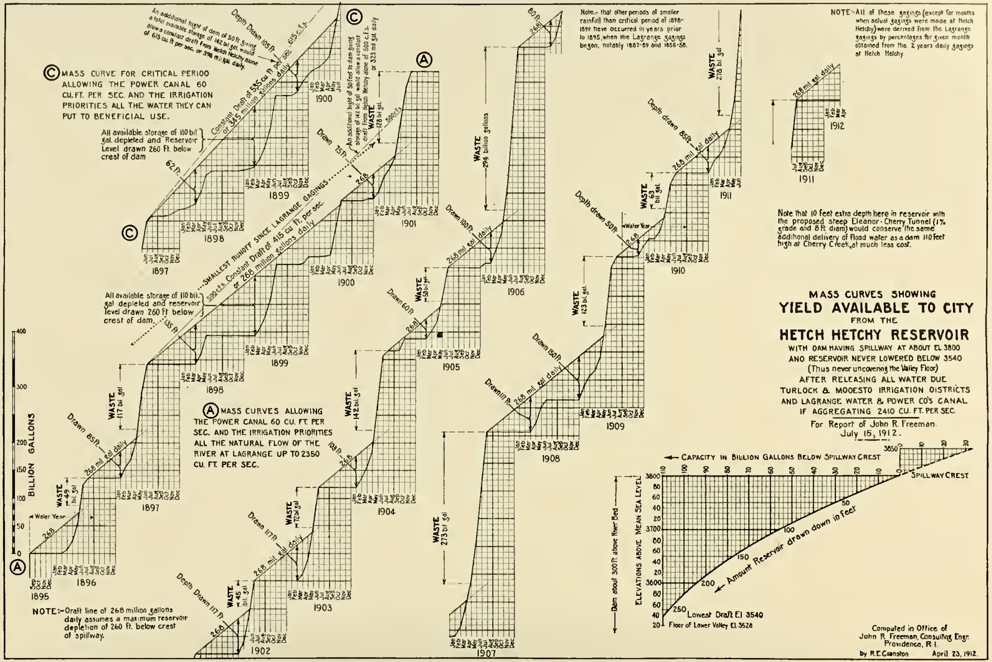
The Eleanor rain gauge is properly exposed and sets at about elevation 4,650. The average elevation of catchment is about 7,400.

The Hetch Hetchy rain gauge is properly exposed and sets at about elevation 3,530. The average elevation of catchment is about 8,800.

The Cherry rain gauge sets at about elevation 4,500. The average elevation of catchment is about 7,900.

Above results prove that the precipitation on these mountain catchments greatly exceeds that at the valley outlet.

Rainfall and run-off for August, 1912, assumed for Hetch Hetchy in order to round out the year. For Eleanor, both July and August, 1912, are assumed prior to receipt of records. These assumptions cannot be enough in error to materially affect the result for the seasonal year 1911-12, which is of special interest because of small winter precipitation.



MASS CURVES SHOWING
YIELD AVAILABLE TO CITY
FROM THE
HETCH HETCHY RESERVOIR
WITH DAM HAVING SPILLWAY AT ABOUT EL 3800
AND RESERVOIR NEVER LOWERED BELOW 3540
(Thus never uncovering the Valley Floor)
AFTER RELEASING ALL WATER DUE
TURLOCK & MODESTO IRRIGATION DISTRICTS
AND LAGRANGE WATER & POWER CO'S CANAL
IF AGGREGATING 2410 CU. FT. PER SEC.
For Report of John R. Freeman.
July 15, 1912.

Ⓒ MASS CURVE FOR CRITICAL PERIOD ALLOWING THE POWER CANAL 60 CU. FT. PER SEC. AND THE IRRIGATION PRIORITIES ALL THE WATER THEY CAN PUT TO BENEFICIAL USE.

Ⓐ MASS CURVES ALLOWING THE POWER CANAL 60 CU. FT. PER SEC. AND THE IRRIGATION PRIORITIES ALL THE NATURAL FLOW OF THE RIVER AT LAGRANGE UP TO 2350 CU. FT. PER SEC.

Note.- that other periods of smaller rainfall than critical period of 1898-1899 have occurred in years prior to 1895, when the Lagrange gagings began, notably 1887-89 and 1856-58.

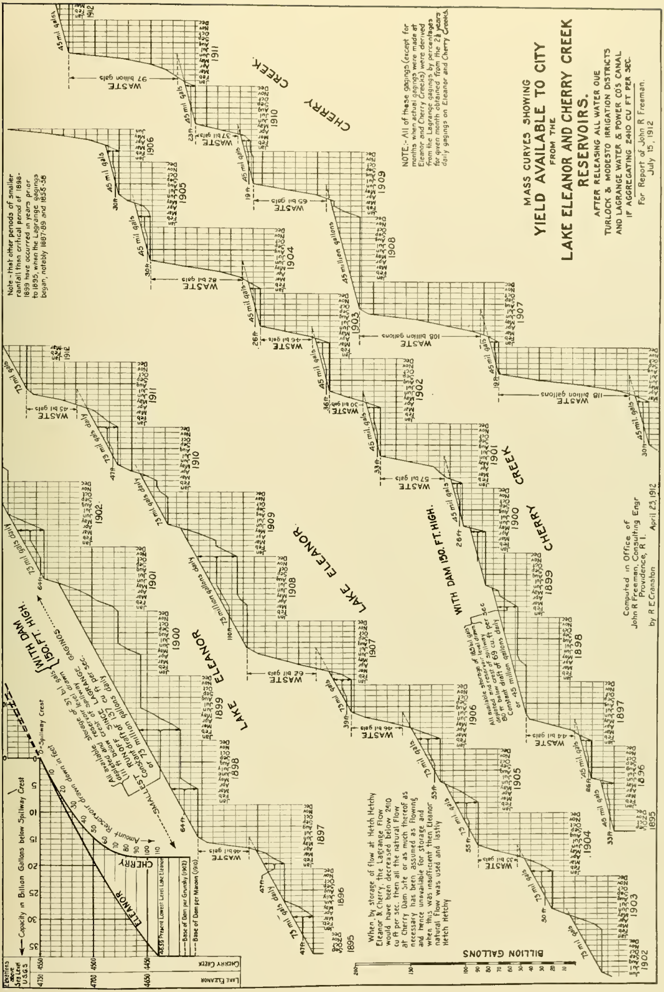
NOTE:-All of these gagings (except for months when actual gagings were made at Hetch Hetchy) were derived from the Lagrange gagings by percentages for given month obtained from the 2 years daily gagings at Hetch Hetchy.

Note that 10 feet extra depth here in reservoir with the proposed steep Eleanor-Cherry Tunnel (1% grade and 8 ft diam) would conserve the same additional delivery of flood water as a dam 110 feet high at Cherry Creek, at much less cost.

NOTE:-Draft line of 268 million gallons daily assumes a maximum reservoir depletion of 260 ft. below crest of spillway.

Computed in Office of
John R. Freeman, Consulting Engr.
Providence, R. I.
by R. E. Cranston April 23, 1912.

BILLION GALLONS
0
50
100
150
200
300
400
Water Year
268
WASTE 49 bil. gal
WASTE 117 bil gal
Drawn 85 ft.
268 mil gal daily
1895
1896
1897
1898
1899
1900
1901
62 ft.
Depth Drawn 105 ft
615 c.f.s.
Constant Draft of 535 cu ft per sec or 345 million gallons daily
An additional hight of dam of 50 ft giving a total available storage of 142 bil gal. would allow a constant draft from Hetch Hetchy alone of 615 cu ft per sec. or 398 mil gal. daily.
All available storage of 110 bil gal. depleted and Reservoir Level drawn 260 ft. below crest of dam
SMALLEST RUNOFF SINCE LAGRANGE GAGINGS
500 c.f.s. Constant Draft of 415 cu ft per sec. or 268 million gallons daily
All available storage of 110 bil. gal depleted and reservoir level drawn 260 ft below crest of dam.
135 ft
Drawn 75 ft
An additional hight of 50 feet to dam giving storage of 142 bil gal would allow a constant draft from Hetch Hetchy alone of 500 c.f.s. or 323 mil gal daily
WASTE 128 bil gal
500 c.f.s.
Ⓐ
Ⓒ
WASTE 294 billion gallons
Drawn 100 ft.
Drawn 60 ft
WASTE 58 bil gal
WASTE 142 bil gal
WASTE 72 bil gal
WASTE 45 bil gal
Depth Drawn 117 ft
Drawn 117 ft
103 ft
1902
1903
1904
1905
1906
1907
WASTE 273 bil gal
Drawn 117 ft.
Drawn 150 ft.
WASTE 123 bil gal
Depth drawn 50 ft.
Water Year
WASTE 63 bil gal
Depth drawn 85 ft.
WASTE 278 bil gal
80 ft.
1908
1909
1910
1911
1912
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
CAPACITY IN BILLION GALLONS BELOW SPILLWAY CREST
ELEVATIONS ABOVE MEAN SEA LEVEL
Dam about 300 ft. above River Bed
3850
3800
3700
3600
SPILLWAY CREST
Amount Reservoir drawn down in feet
50
100
150
200
250
Lowest Draft El 3540
Floor of Lower Valley El 3520



Note - that other periods of smaller rainfall than critical period of 1898-1899 have occurred in years prior to 1895, when the Lagrange gagings began, notably 1887-89 and 1855-58

NOTE:- All of these gagings (except for months when actual gagings were made at Eleanor and Cherry Creeks) were derived from the Lagrange gagings by percentages for given month obtained from the 2½ years daily gagings on Eleanor and Cherry Creeks.

All available storage of 57 bil gals depleted and reservoir level drawn below crest of spillway. SMALLEST RUNOFF SINCE LAGRANGE GAGINGS began 137 cu ft per sec. Constant draft of 73 million gallons daily

All available storage of 18.5 bil gals depleted and reservoir level drawn 80 ft below crest of spillway. Constant draft of 69 cu. ft. per sec or 45 million gallons daily

When, by storage of flow at Hetch Hetchy Eleanor & Cherry, the Lagrange Flow would have been decreased below 2410 cu ft per sec. then all the natural Flow at Cherry Dam Site or as much thereof as necessary has been assumed as flowing and hence unavailable for storage and when this was insufficient then Eleanor natural Flow was used and lastly Hetch Hetchy

Computed in Office of
John R Freeman, Consulting Engr
Providence, R. I.
by R E Cranston April 23, 1912

Surveys on Which Present Plans Are Based

(114) The accompanying maps and sections along the tunnel line were first laid out upon sheets of the published contour maps of the U. S. Geological Survey, except at the crossing of the broad San Joaquin Valley, for which no such sheets have yet been published. For this part, recourse was had to Sheet No. 1 of the Topographical and Irrigation Map of the San Joaquin Valley, on a scale of one inch to three miles, published by the California State Engineering Department in 1886 This information was supplemented by the actual survey made under the supervision of C. E. Grunsky, in 1901, for his pipe line across this valley.

Since our location was farther south than the Grunsky location and since the state map was incomplete in its details of the foot-hill topography on both sides of the valley, two survey parties were dispatched in June, 1912, to run levels and outline the topography while seeking the most favorable support for the aqueduct thru the foothills. The country here is so irregular and the land marks so very few, section corners being hard to pick up, that it has not, up to the present time, been possible to work out the details for a few miles at each edge of the valley with the completeness desired, particularly on the easterly side. Photo etchings on a small scale of the sheets of this new survey (of the accuracy of which I am uncertain) are included in the appendix so far as completed, also new surveys have been made very recently for Early Intake power house sites and the river crossings.

The reconnaissance and the levels show that this construction at both margins of the San Joaquin Valley is feasible and will not be costly and the present uncertainty relates chiefly to a choice of routes and location of point where change is made from tunnel to pipe at the easterly margin of the San Joaquin Valley and as to the precise distance on which steel pipe or surface conduit may be substituted for tunnel.

All of the elevations shown on the profiles and the distances and contours shown on the present maps are taken from the topographic sheets after first applying such corrections as have recently been determined by means of the levelers employed by the City Engineer.

Correction of Levels

(115) The leveling up into these reservoir sites has not yet been done in a precise or satisfactory manner. A single line of levels carried recently at my request by the City Engineer's department (from the railroad bench marks near Oakdale up into the Hetch Hetchy Valley) indicates that about 130 feet should be deducted from the elevations of the floor of this valley shown by the contours on the topographic sheet and a similar amount from the Grunsky reservoir contours of 1902, both of which were based on the same U. S. G. S. barometric datum. No line of actual levels was run up to Hetch Hetchy in 1902 and the Grunsky side hill canal locations of 1901-2, because of economy, haste and roughness of the country, appear to have been mainly "paper locations" on a large scale plane table map of the whole canyon on which the located points were rather far apart.

Similarly, we now find at Lake Eleanor that in order to get the true low-water elevation of the lake and presumably of the adjacent contours, somewhere about 55 feet must be deducted from the elevations of the U. S. G. S. topographic sheet of the Yosemite quadrangle, edition 1909, reprint of 1911.

At the Cherry Creek reservoir site, reliance for elevations and dimensions is placed upon the surveys of Mr. Wm. Hammond Hall in connection with his proposed development of water power and reservoir property which he subsequently sold to the city.

Correction of Contours, U. S. Geological Survey Topographic Maps

(116) In such an extremely rough country as covered by this Yosemite quadrangle it is not to be expected that the contours on these topographic maps are everywhere drawn with precision, and the work is now in progress of testing the altitude by new levels to each of our important shaft sites.

The following points of difference have thus far been noted: (Subject to revision after more precise leveling.)

	By City Engineer (Jones).	By U.S.G.S. Contours.	Difference Feet.
At Red Mountain Bar the ordinary water level of the Tuolumne River on May 28, 1912, was found	524.5		
The map contour roughly indicated an elevation of........		690.	
Therefore deduct from elevation by map			165.5
At Moffatt Bridge, ordinary water level was found............	599.5		
The contour roughly indicates about		800.	
Therefore from the map elevation deduct..............			200.
At the confluence of Moccasin Creek with the Tuolumne the ordinary water level was found to be	647.		
The contour indicates......		890.	
Therefore deduct from map elevation			243.

Close to the site of our Power House No. 1, at the point where the road to Priests crosses Moccasin Creek the ordinary water level was found......	886.		
where the contour indicated...		1100.	
Therefore deduct from elevation on map..............			215.
At Priests Hotel, levels show an elevation................	2824.		
instead of by contours about..		3000.	
Therefore deduct from elevation on map................			176.
At the confluence of the South Fork with the Tuolumne a mile below Lumsdens Bridge, the ordinary water level was found..................	1461.		
where the contour was roughly about................		1800.	
showing there should be deducted.................			40.
At the confluence of Cherry Creek with the Tuolumne a bench mark at the cabin was found of....................	2173.		
from which it is roughly estimated................			
the ordinary water level is about..................	2115.		
where the contours indicate...		2265.	
which indicates that about....			150.
should be deducted at this point.			
At the early intake the ordinary water level is found........	2251.5		
the contour map shows about.		2450.	
therefore there should be deducted about............			200.

It is unfortunate that at the beginning of the City Engineer's investigation a line of well checked bench levels was not run all the way from tidewater up into the Hetch Hetchy and Cherry region with plenty of permanent bench marks left along the highway and the river crossings. There is now liability to confusion and error from the many maps extant on which the elevations are marked from an incorrect datum. The next step in surveys should be an accurate line of bench levels and permanent bench marks on bolts set in ledge with heights cut into the stone all along.

Accuracy of the Preliminary Location Data

(117) I believe we have already carried the check levels far enough so that no error in elevation can exist that would seriously affect our present problems. The amount of accurate surveying done on lines useful for the present studies has not been so large as I would have liked, still by the aid of the U. S. G. S. topographic maps, supplemented by the careful reconnaissance of Mr. Horace Ropes, a Civil Engineer of wide experience, both in railroad and in aqueduct location, we have checked up the various points of control on the project as now presented, and I have no doubt that the course and distances shown for the aqueduct, as well as the elevations, are sufficiently correct for all present purposes.

We were fortunate in the fact that the topographic sheets of the U. S. Geological Survey covered nearly all parts of the line, and were thus enabled to make many trial locations on paper before selecting the present positions, prior to our final reconnaissance in the field.

Since the working out of present plans, in July, 1912, detailed surveys have been made, under my instructions, by Mr. W. C. Hammatt, C. E., of the Early Intake and power house site and the positions marked on the ground. A survey has also been made of power house site No. 1, and sketch studies of outlines of works at both these points prepared as a basis for estimates of cost.

Geological Reconnaissance

(118) In any important project involving tunnelling or deep shaft sinking it is of the utmost importance for the engineer to supplement his topographic studies by the best geologic insight beneath the surface that it is possible to obtain; for the signs of fault zones and water-bearing strata are seldom sufficiently obvious to anyone but the specialist whose eye has been trained by many years of study in that particular region, or in one of similar geology. In the present instance we were fortunate in securing the aid of Prof. J. C. Branner, Vice-President of Stanford University, than whom there is no one with more profound knowledge concerning the geology of the region through which the most difficult of our tunnels are to pass. The fact that Professor Branner is a specialist in tracing fault lines and in whatever pertains to intensity of earthquake shock has also given a special value to his advice.

Professor Branner has long been interested in tracing out the structure of this particular region and I am told by other geologists that the geologic folios that will cover the coast range portion of our route which are in preparation for publication by the U. S. Geological Survey, will draw largely on his studies for their facts.

Along the central portion of our tunnel line the region is covered by the Sonora folios of the U. S. Geological Survey and this section has long been an inviting field for the studies of geologists, because of being crossed by the famous gold-bearing Mother Lode district of California. Many successful mines are now being operated in this district, and these have added to the geologic interpretation and have demonstrated the character of many of these formations as regards facility of tunnelling.

In co-operation with Mr. Horace Ropes, Locating Engineer, Prof. Branner reconnoitered substantially the entire line of tunnels that I have proposed between the Hetch Hetchy and San Francisco. Not all the hills and mountains along the precise location were climbed but by the aid of previous knowledge and a study of such points as could be reached rapidly over the highways by automobile and with various side trips here and there for the study of variants, in the course of four days of field work, supplemented by office studies by Professor Branner, the preliminary topographic location was changed because of geologic conditions to a new location shown on the accompanying drawings.

Aqueduct Line Changed from Geologic Consideration

(119) Several extremely important modifications from our first topographic location were made on the advice of Professor Branner, for the purpose of avoiding what promised to be difficult ground. For example, approaching Red Mountain Bar the line was shifted to the south to avoid a belt of serpentine in which it was feared tunnelling might prove difficult because of the slippery broken character of this rock.

More modifications were made in crossing the coast range district. The topography favored a line near the Western Pacific branch to Tesla, because of the transportation facilities and in order to secure shallower shafts; and the fact that the Tesla mines were worked for many years, though now abandoned, suggested that notwithstanding these were reported to have been in heavy, swelling ground, the very existence of extensive deep workings proved that it was possible to excavate drifts at moderate cost and the knowledge that this country had been mined encouraged the idea that permanence could be secured in an aqueduct tunnel having a thick concrete lining, everywhere arched by its circular form so as to withstand a pressure far beyond capabilities of any mine timbering. The plans of the Tesla coal workings were therefore borrowed and studied.

However, Prof. Branner finds that by shifting the line one or two miles southerly from the location of the Tesla Railroad and by continuing it easterly toward our Irvington gatehouse on a line also farther south, and with deeper shafts than would be otherwise required, apparently it will be possible to make substantially the entire length of this tunnel in favorable rock and to avoid mostly, if not wholly, the difficulties that would be found in the vast deposit of deep Pliocene gravels lying along the route, one, two or three miles farther north, which gravels are probably water-bearing. I desire to make plain my deep appreciation of the advice given by Professor Branner.

An inspection of the relief map in the front of this report also makes plain the reasonableness of shifting the line south to avoid the gravels.

At the bottom of each of the accompanying drawings, which show the proposed aqueduct location, a geological section is given, based on a section drawn on natural scale furnished by Prof. Branner in connection with his map of the geologic structure. Upon this condensed longitudinal scale it has not been practical to portray accurately the location of the synclines and the anti-clines or the dip of the strata.

The geologic sections are of great interest in indicating fairly good tunnel ground all along the line, but as stated elsewhere, fully a year, and perhaps two years, of continuous additional engineering study should be given to the matter of determining the best possible location, by means of hundreds of diamond drill holes and a large amount of geologic field work.

It is of interest to note that our tunnel cuts directly through the region of the famous gold-bearing "mother lode."

Prof. Branner's report follows:

(120) REPORT BY PROFESSOR J. C. BRANNER.

Office of the Vice-President,
Stanford University, Cal., July 1, 1912.

John R. Freeman, Consulting Engineer.

Sir—I have gone over the line of the conduit proposed by you for bringing water from the upper Tuolumne River and from the Hetch Hetchy Valley to San Francisco, and have examined the general geology of the route with a view to determining the nature of the geology in its bearing upon the construction of the tunnels and other necessary structures.

The general geology along the line is shown on the accompanying map[*] and sections which require but little further explanation.

In so far as the geology is concerned the route selected and as indicated by you on the accompanying map, is entirely feasible.

Possible Danger From Earthquakes.—It is to be noted, however, that this line cuts square across the geological structure—that is, across the folds and faults—of the region between the Hetch Hetchy Valley and San Francisco. It is also a matter of common information that California is a part of the region of rather high seismicity, and inasmuch as the line of the conduit crosses many faults, it is to be expected that displacements are liable to occur sooner or later. But with our present knowledge of the geology and of the relations of geology to earthquake intensities the injury liable to be caused by earthquakes can be partly avoided and partly provided against, especially when a more detailed study of the geology shall have disclosed the exact points at which disturbances are most likely to occur.

At present I can call attention to two places which cannot be avoided and at which special provisions will need to be made for possible interruptions by earthquakes. One of these is just north of the town of Irvington, where there is evidence of a recently active fault line which the pipes of the system must necessarily cross. This point can probably be located within a distance of a hundred feet.

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[*] The map is not reproduced because it is colored in conventional geologic tints. The notes of Professor Branner's sections have been transferred to the condensed profile shown at bottom of pages 112 to 117. Unfortunately, they could not be conveniently reproduced on natural scale to show the angle of dip of the strata.—J. R. F.

The other point is where the line crosses the San Joaquin River. The danger at the last named place, however, is not due to the presence of a fault line, but simply to the soft and wet condition of the ground which would favor high intensity in case of a rather severe earthquake in the neighborhood.

(121) *Rocks to be Encountered.*—The following statement in regard to the nature of the rocks to be encountered in the proposed tunnels and cuts must be regarded as general rather than specific. In order to speak precisely it will be necessary to know more definitely than can be known at present the location and depth of the tunnels along the entire route.

Beginning near Irvington and referring to the miles indicated on the accompanying map the rocks are as follows:

From mile		
46	to 47½,	aluvium.
47½	to 50½,	Santa Margarita sandstone.
50½	to 51,	Knoxville shale and sandstone.
51½	to 55½,	Santa Margarita sandstone.
55½	to 58,	Franciscan sandstone, shale and schist.
58	to 61½,	Knoxville and Chico sandstone and shale.
61½	to 72,	Franciscan sandstone and schist.
72	to 75¼,	Santa Margarita (?) sandstone and shale.
75¼	to 80,	Pliocene gravel, sand and clay.
80	to 107,	alluvial soil, etc., of the San Joaquin Valley floor.
107	to 123,	volcanic tuff in the high ground.
123	to 132¼,	porphyrite (altered lava).
132¼	to 133,	Mariposa slate, nearly vertical.
133	to 133¼,	porphyrite (altered lava).
133¼	to 133¾,	Mariposa slate, vertical.
133¾	to 134,	porphyrite (altered lava).
134	to 135,	mostly granite.
135	to 137½,	amphibolite (altered eruptive).
137½,		short distance in serpentine.
137½	to 139½,	porphyrite.
139½	to 141,	Mariposa slate, dipping east 60 degrees.
141	to 142½,	porphyrite (altered lava).
142½	to 145½,	Calaveras quartzite, schist, and shale interbedded.
145½	to 146¾,	granite.
146¾	to 150,	Calaveras quartzite, schist and shale interbedded.
150	to 151,	andesite tuff.
151	to 155½,	Calaveras quartzite, schist and shale.
155½	to 173½,	granite and granodiorite.
173½		to the end of the Cherry Valley line, granite.

TOTALS

(not including the line from Cherry Creek to Hetch Hetchy).

	Rocks.	Approximate miles.	
1.	Alluvial (soil, sand, adobe, clay).....	28½	Not to be tunneled.
2.	Unaltered tuff	15½	
3.	Pliocene gravel, sand and clay.......	8¼	
4.	Santa Margarita sandstone and shale..	8	To be tunneled.
5.	Monterey shale	1	
6.	Chico sandstone and shale...........	2¼	
7.	Knoxville shale and sandstone........	½	
8.	Franciscan schist and sandstone.......	12	
9.	Mariposa slate	2	
10.	Calaveras quartzite, schist and shale...	12	
11.	Serpentine	(?)	
12.	Amphibolite (altered eruptive)	4	
13.	Porphyrite (altered lava)	11	
14.	Granite	17½	

(122) *Character of the Rocks for Tunneling.*—Aside from the local bad spots that no one can possibly determine in advance, the characters of the rocks that occur on the line of the conduit are well known to the mining engineers in this State.

Perhaps the most difficult ones to deal with are the so-called Mariposa slates which form a belt a little more than two miles wide just west of Moccasin Creek. These same slates are found in many of the California mines. The Eagle-Shawmut mines, near Jacksonville, are in them.

The Mariposa slates stand nearly on end, and the line strikes them at an advantageous angle.

It will be understood that there are liable to be zones of bad ground in any of the rocks which the geologist cannot possibly foresee.

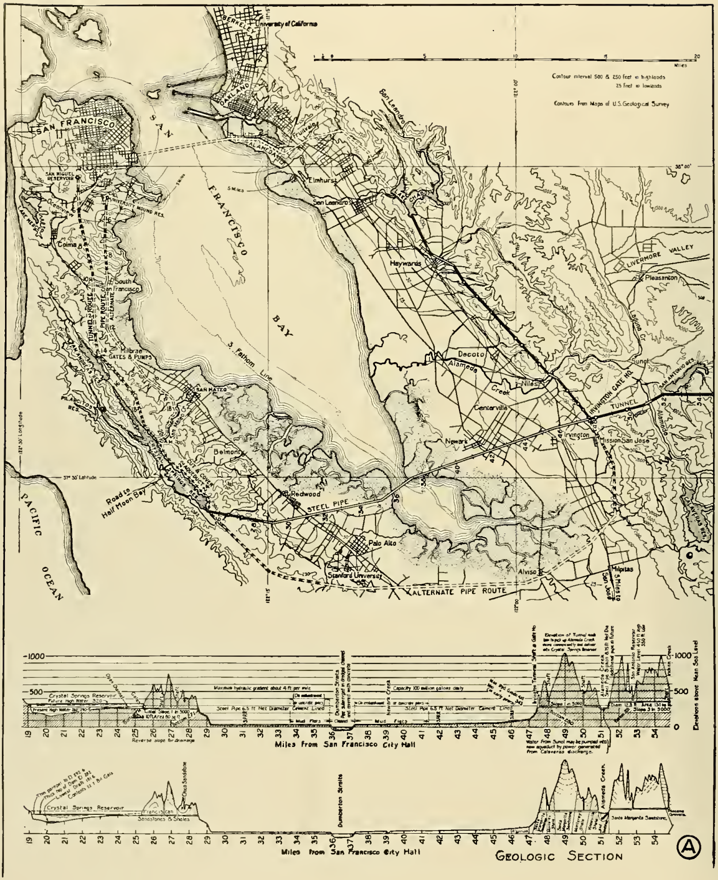
No great concern need be felt about the effects of pressure upon the rocks in the deepest of the proposed tunnels.

The profile of the line shows that the tunnels will have a maximum depth below the surface of 1,700 feet.

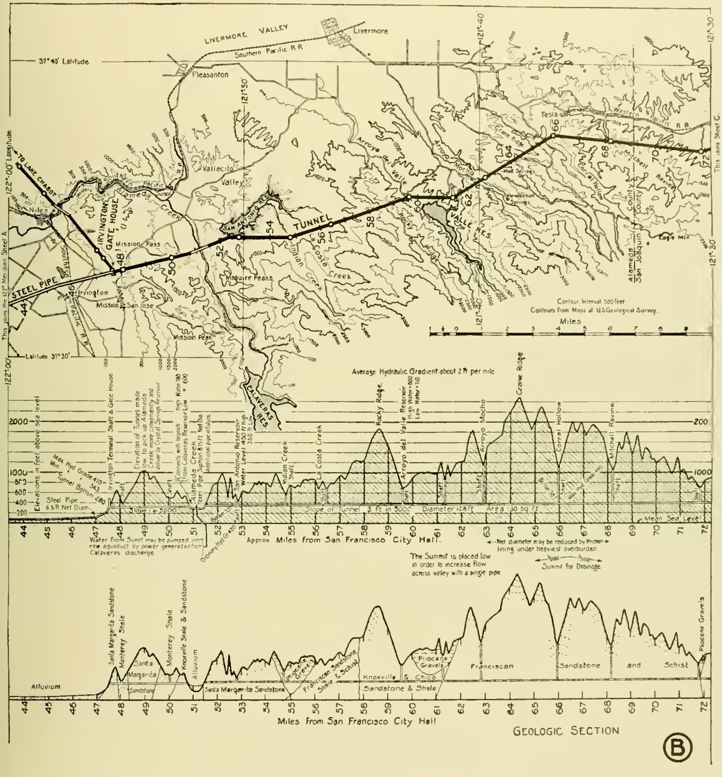
There are several mines in California with a depth of more than 2,000 feet, and some deeper than 3,000 feet, in which the difficulties from pressure are not serious.

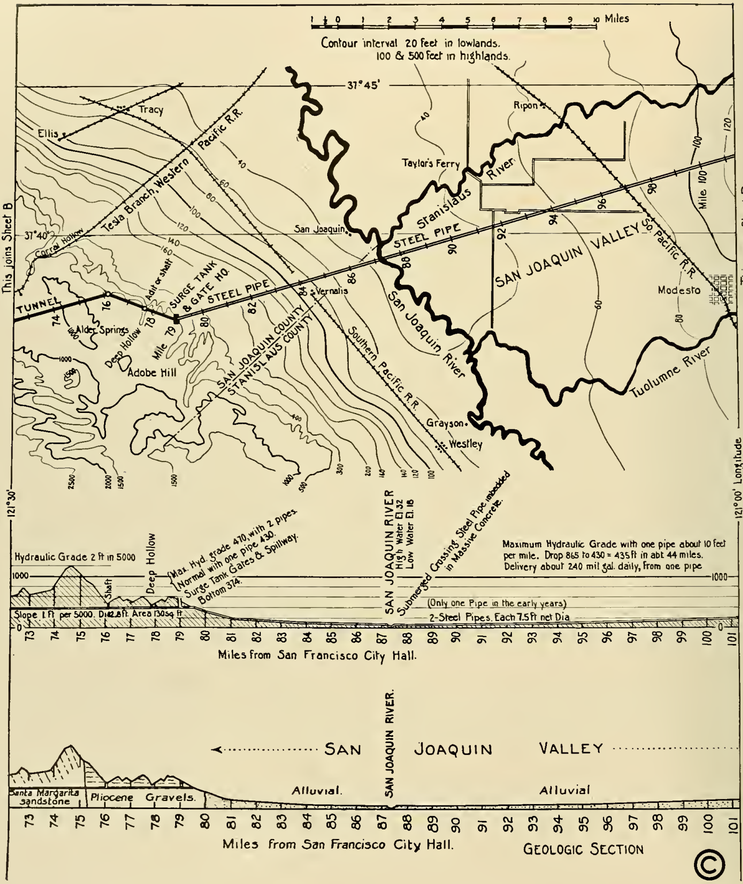
Yours with respect,

(Signed): J. C. BRANNER,
Consulting Geologist.

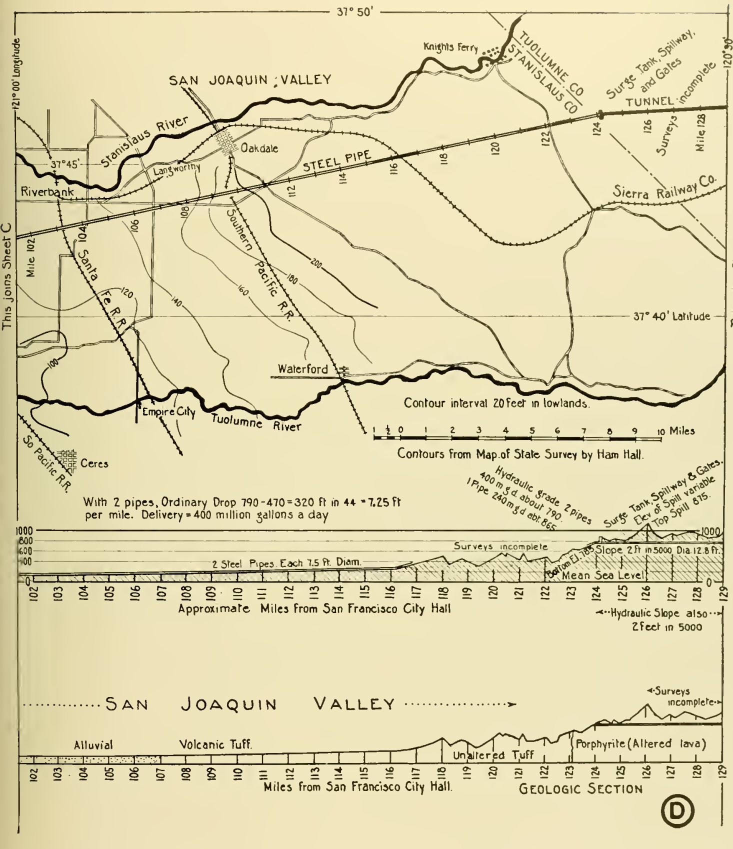

Contour interval 500 & 250 feet in highlands
25 feet in lowlands
Contours From Maps of U.S. Geological Survey
Miles
SAN FRANCISCO
BERKELEY
University of California
OAKLAND
ALAMEDA
Fruitvale
Elmhurst
San Leandro
Haywards
LIVERMORE VALLEY
Pleasanton
Decoto
Alameda Creek
Niles
Centerville
Newark
Irvington
Mission San Jose
IRVINGTON GATE HO.
TUNNEL
Sunol
SAN ANTONIO RES.
CALAVERAS RES.
SAN MIGUEL RESERVOIR
UNIVERSITY MOUND RES.
LAKE MERCED
Oceanview
Colma
South San Francisco
TUNNEL ROUTE
PIPE ROUTE ALTERNATE
Millbrae GATES & PUMPS
SAN ANDREAS
PILARCITOS RES.
SAN MATEO
Belmont
CRYSTAL SPRINGS RES.
CUT & COVER AQUEDUCT
Redwood
STEEL PIPE
Palo Alto
Stanford University
Alviso
Milpitas
San Jose 5 Miles to
ALTERNATE PIPE ROUTE
Road to Half Moon Bay
SAN FRANCISCO BAY
3 Fathom Line
PACIFIC OCEAN
37° 30' Latitude
122° 30' Longitude
Crystal Springs Reservoir
Future High Water 320
Present High Water 292
Open Channel
Gate
Tunnel Slope 1 in 5000 10 ft Area 80 sq ft
Bottom 271
Shaft
Reverse slope for drainage
Maximum hydraulic gradient about 4 ft per mile
On embankment
on concrete piers
Steel Pipe 6.5 ft Net Diameter Cement Lined
Mud Flats
Channel
Dumbarton Straits
Pipe submerged in dredged channel and covered with concrete
Newark Creek
Capacity 100 million gallons daily
Irvington Terminal Shaft & Gate Ho.
Elevation of Tunnel made low to pick up Alameda Creek
Slope 1 in 5000
Bottom 280
Alameda Creek
San Antonio Reservoir Water Level 450 ft High 350 ft Low
Indian Creek
Slope 3 in 5000
Water From Sunol may be pumped into new aqueduct by power generated From Calaveras discharge.
1000
500
0
Elevations above Mean Sea Level
Miles From San Francisco City Hall
Top parapet to El 292.6
Crystal Springs Reservoir
Franciscan
Sandstones & Shales
Chico Sandstone
Dumbarton Straits
Alameda Creek
Santa Margarita Sandstone
GEOLOGIC SECTION
Ⓐ

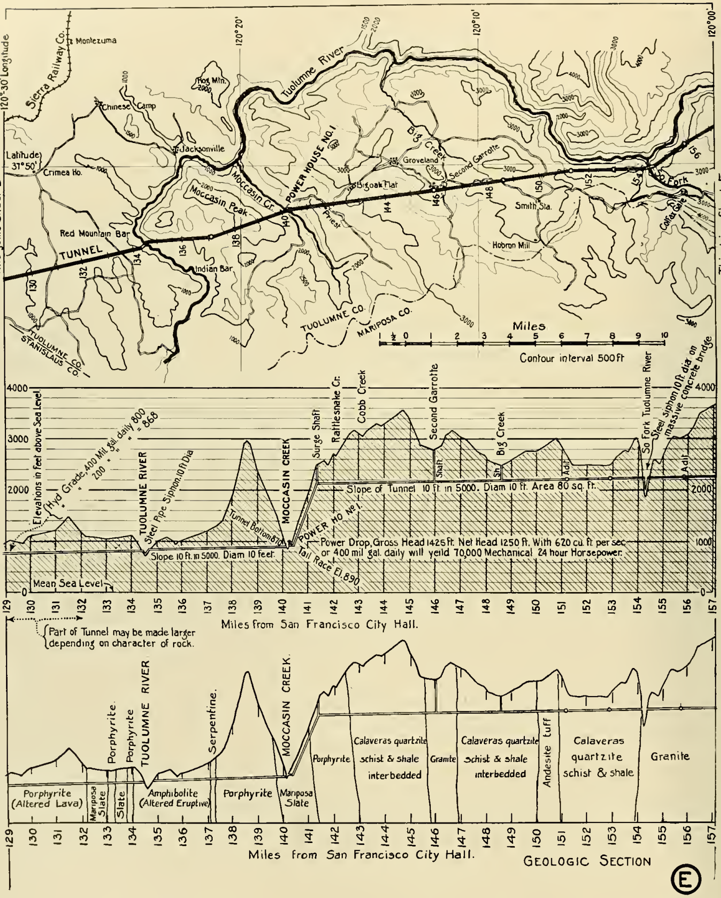
PLANS AND SECTIONS OF AQUEDUCT LOCATION IN COAST RANGE



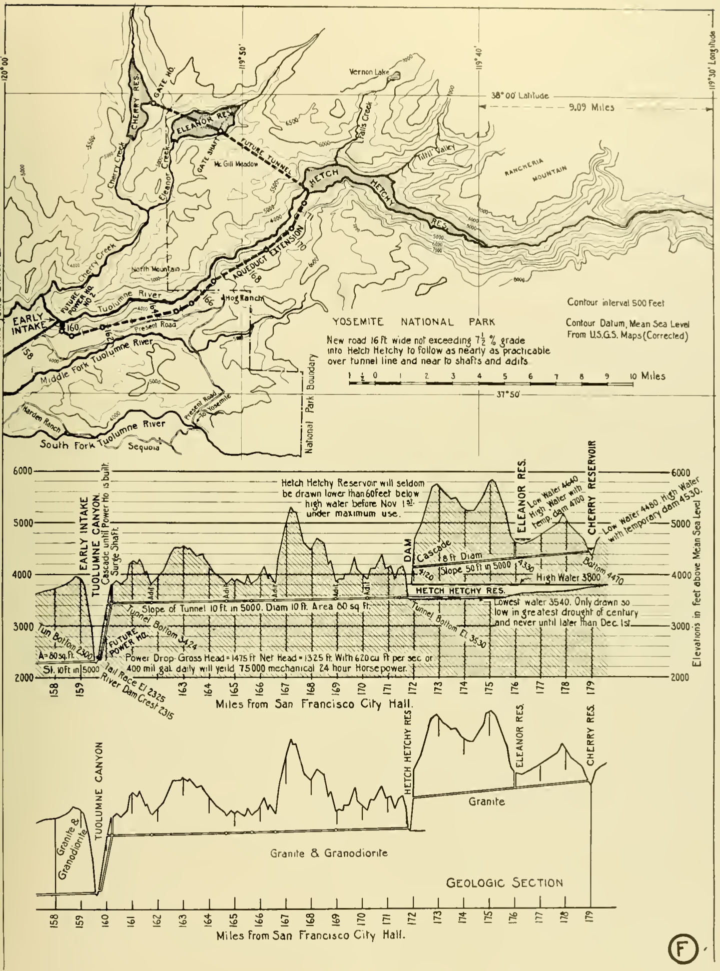

Miles
Contour interval 20 feet in lowlands.
100 & 500 feet in highlands.
37°45'
37°40'
121°30'
121°00' Longitude
This joins Sheet B
This joins Sheet D
Tracy
Ellis
Tesla Branch, Western Pacific R.R.
Corral Hollow
TUNNEL
Alder Springs
Deep Hollow
Adobe Hill
Adit or Shaft
SURGE TANK & GATE HO.
STEEL PIPE
Mile 79
Vernalis
San Joaquin
Taylor's Ferry
Ripon
Stanislaus River
SAN JOAQUIN VALLEY
So. Pacific R.R.
Modesto
Mile 100
San Joaquin River
Southern Pacific R.R.
SAN JOAQUIN COUNTY
STANISLAUS COUNTY
Grayson
Westley
Tuolumne River
Hydraulic Grade 2 ft in 5000
Deep Hollow
Shaft
Max. Hyd. grade 470, with 2 pipes.
Normal with one pipe 430.
Surge Tank Gates & Spillway.
Bottom 374.
SAN JOAQUIN RIVER
High Water El. 32
Low Water El. 18
Submerged Crossing. Steel Pipe imbedded in Massive Concrete.
Maximum Hydraulic Grade with one pipe about 10 feet per mile. Drop 865 to 430 = 435 ft in abt. 44 miles. Delivery about 240 mil. gal. daily, from one pipe
(Only one Pipe in the early years)
2-Steel Pipes. Each 7.5 ft net Dia
Slope 1 ft per 5000. Dia 12.8 ft. Area 130 sq ft
Miles from San Francisco City Hall.
SAN JOAQUIN VALLEY
SAN JOAQUIN RIVER.
Santa Margarita sandstone
Pliocene Gravels.
Alluvial.
Alluvial
Miles from San Francisco City Hall.
GEOLOGIC SECTION

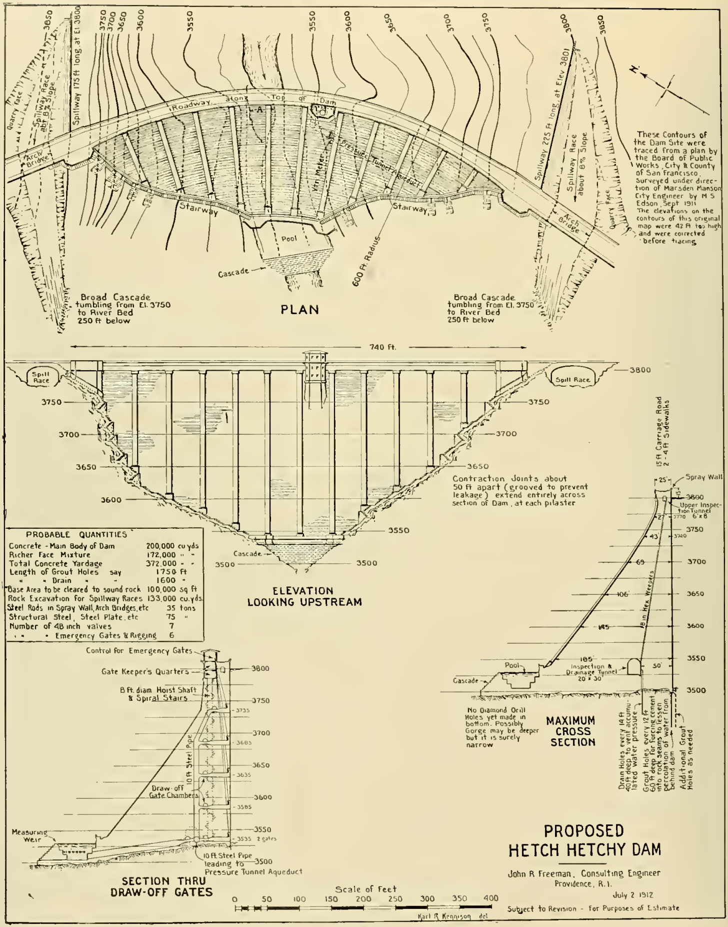
AQUEDUCT LOCATION ACROSS SAN JOAQUIN VALLEY




120°30' Longitude
120°20'
120°10'
120°00'
Latitude 37°50'
This joins Sheet D
This joins Sheet F
Sierra Railway Co.
Montezuma
Chinese Camp
Jacksonville
Crimea Ho.
Red Mountain Bar
Indian Bar
Hog Mtn.
Tuolumne River
Moccasin Cr.
Moccasin Peak
POWER HOUSE NO. 1
Priest
Big Creek
Groveland
Big oak Flat
Second Garrotte
Smith Sta.
Hobron Mill
So Fork
Collar Gate
TUNNEL
TUOLUMNE CO.
MARIPOSA CO.
TUOLUMNE CO.
STANISLAUS CO.
Miles
Contour interval 500 ft
Elevations in feet above Sea Level
Hyd Grade, 400 Mil. gal. daily 800
200 " " " = 868
Steel Pipe Siphon 10 ft Dia
TUOLUMNE RIVER
Tunnel Bottom 870
MOCCASIN CREEK
POWER HO. No. 1
Surge Shaft
Rattlesnake Cr.
Cobb Creek
Second Garrotte
Big Creek
So Fork Tuolumne River
Steel Siphon 10 ft. dia. on massive concrete bridge
Shaft
Sh.
Adit
Slope of Tunnel 10 ft. in 5000. Diam 10 ft. Area 80 sq. ft.
Power Drop, Gross Head 1425 ft. Net Head 1250 ft. With 620 cu. ft. per sec. or 400 mil gal. daily will yeild 70,000 Mechanical 24 hour Horsepower.
Tail Race El. 890
Slope 10 ft. in 5000. Diam 10 feet.
Mean Sea Level
Miles from San Francisco City Hall.
Part of Tunnel may be made larger depending on character of rock.
Porphyrite
Porphyrite
TUOLUMNE RIVER
Serpentine
MOCCASIN CREEK
Porphyrite (Altered Lava)
Mariposa Slate
Slate
Slate
Amphibolite (Altered Eruptive)
Porphyrite
Mariposa Slate
Porphyrite
Calaveras quartzite schist & shale interbedded
Granite
Calaveras quartzite schist & shale interbedded
Andesite tuff
Calaveras quartzite schist & shale
Granite
Miles from San Francisco City Hall.
GEOLOGIC SECTION
E

AQUEDUCT LOCATION NEAR THE HETCH HETCHY




PLAN
3850
Spillway 175 ft long, at El 3800
3750
3700
3650
3600
3550
3550
3600
3650
3700
3750
3800
3850
Quarry face
Spillway Race abt 8% Slope
Arch Bridge
Roadway along Top of Dam
A
Pressure Tunnel Aqueduct
Venturi Meter
Stairway
Stairway
Pool
Cascade
600 ft. Radius
Spillway 225 ft long, at Elev 3801
Spillway Race about 8% Slope
Quarry Face
Arch Bridge
N
Broad Cascade tumbling from El. 3750 to River Bed 250 ft below
Broad Cascade tumbling from El. 3750 to River Bed 250 ft below
740 ft.
Spill Race
Spill Race
3800
3750
3750
3700
3700
3650
3650
3600
3550
Cascade
3500
3500
ELEVATION LOOKING UPSTREAM
15 ft Carriage Road 2 - 4 ft Sidewalks
25'
Spray Wall
15'
3800
Upper Inspection Tunnel 6' x 8
27'
3770
3750
43'
3740
69
3700
106'
3650
18 in Hex Weepers
145
3600
185'
3550
Pool
Inspection & Drainage Tunnel 20' x 30'
50'
Cascade
3500
MAXIMUM CROSS SECTION
Drain Holes every 14 ft 40 ft deep to vent accumulated water pressure
Grout Holes every 12 ft 60 ft deep for forcing cement into rock seams to lessen percolation of water from behind dam
Additional Grout Holes as needed
Control for Emergency Gates
Gate Keeper's Quarters
3800
8 ft. diam Hoist Shaft & Spiral Stairs
3750
3735
3700
3685
10 ft Steel Pipe
3650
3635
Draw-off Gate Chambers
3600
3585
Measuring Weir
3550
3535 2 gates
10 ft. Steel Pipe leading to Pressure Tunnel Aqueduct
3500
SECTION THRU DRAW-OFF GATES
Scale of Feet
0
50
100
150
200
250
300
350
400
Karl R Kennison del

These Contours of the Dam Site were traced from a plan by the Board of Public Works, City & County of San Francisco. Surveyed under direction of Marsden Manson City Engineer by M S Edson, Sept 1911. The elevations on the contours of this original map were 42 ft too high and were corrected before tracing

Contraction Joints about 50 ft apart (grooved to prevent leakage) extend entirely across section of Dam, at each pilaster

No Diamond Drill Holes yet made in bottom. Possibly Gorge may be deeper but it is surely narrow

PROBABLE QUANTITIES

Concrete - Main Body of Dam	200,000	cu yds
Richer Face Mixture	172,000	" "
Total Concrete Yardage	372,000	" "
Length of Grout Holes say	1750	ft
" " Drain " "	1600	"
Base Area to be cleared to sound rock	100,000	sq ft
Rock Excavation for Spillway Races	133,000	cu. yds.
Steel Rods in Spray Wall, Arch Bridges, etc	35	tons
Structural Steel, Steel Plate, etc	75	"
Number of 48 inch valves	7	
" " Emergency Gates & Rigging	6	

PROPOSED
HETCH HETCHY DAM

John R Freeman, Consulting Engineer
Providence, R. I.
July 2 1912

Subject to Revision - For Purposes of Estimate

The Hetch Hetchy Dam

(123) The design proposed is shown in the accompanying drawing. In its general outlines it is much the same as the dam that I designed last year for the California Gas & Electric Company at the outlet of Lake Spaulding, and on which construction work is now being carried on vigorously. Although twice as tall as the dam proposed at this site ten years ago, this Hetch Hetchy dam will not be so tall as that on the Boise River, now under construction by the U. S. Reclamation Service, which I have previously had occasion to visit and study, nor will it be under nearly such difficult conditions. It is of substantially the same type as the two dams now under construction by the Board of Water Supply of New York City, for which I have acted as Consulting Engineer, and is given more liberal architectural treatment than is common with masonry dams, in deference to its location in a National Park, and that it may be of itself an object of interest to visitors, as are the dams on certain of the great English works to which I have already referred.

No borings have yet been made at the site, but from a careful personal examination of the character of the rock formation and the shape of the gorge I am confident the site involves no great difficulty. The depth of the gravel and boulder-filled gorge is probably less than at the Boise or Shoshone dams. Attention is called to the photograph of this site in the front of this report. Cyclopean concrete is the material proposed.

Regarding a Still Higher Dam

(124) The mass curves or summation hydrographs presented on a previous page show that there will be water enough delivered from the catchment into the Hetch Hetchy reservoir to warrant the construction of a dam fully 25 feet higher than that for which the drawing is presented, and a dam of that height would not be materially beyond precedent of those now under construction on the Boise River and on the Yuba River, and on this remarkably favorable site would involve no special difficulties other than that of the increased cost and increased time for building because of containing larger mass of masonry. If the remarkable water power opportunities along these aqueducts elsewhere described were to be a controlling feature of the design, regard for the principles of conservation would direct one to make this dam at least 25 feet and possibly 50 feet taller than shown in the drawings, and the possibility that this height may be called for under the development of future years should not be lost sight of in wording the grant by the Federal Government for the necessary lands and rights of way connected with this project.

It is certain that some day the San Francisco bay cities will need all of the water that can be secured by means of the highest practicable dams at Hetch Hetchy, Eleanor and Cherry, and in every grant by the Federal Government and every act by the city, this fact should be constantly kept in view.

A Lower Dam at First

It will probably be found that a very large sum of money can be saved by at first building this dam to much less than its ultimate height, and that this low dam, in connection with the low dams of Eleanor and Cherry, will furnish all of the 240 million gallons daily that the first pipe will carry, or that will be needed for perhaps thirty or forty years.

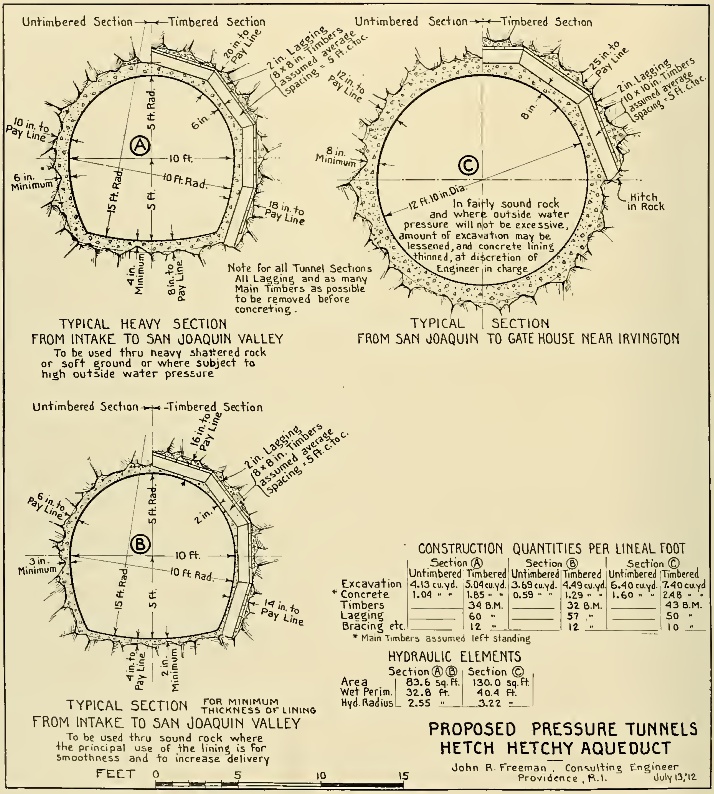
It will be cheapest and best to extend the tunnel from Hetch Hetchy to Eleanor and Cherry and build the low dams at both Eleanor and Cherry immediately after completing the aqueduct below the Early Intake, and as soon as the low Hetch Hetchy dam and the scenic road are completed. This will perhaps make the water rights more secure by use, and at the same time it promises to be the cheapest and most logical order of construction.

Building the Eleanor-Cherry Tunnel

The difficulties of transportation of cement, etc., to the Cherry and Eleanor sites and other reasons indicated above, make it best to build these dams of earth between substantial loose rock fills, thus avoiding all transportation of cement and heavy bulky supplies over the rough wagon road beyond the terminus of the construction railroad at Hetch Hetchy.

The power for quarrying and power for the pumps for sluicing the earth fill, can be carried very cheaply by a transmission line on poles set along the wagon road to Cherry and Eleanor, already mentioned, from an extension from the electric power line used in building the Hetch Hetchy dam.

The Eleanor-Cherry tunnel is only about four miles long to the Eleanor shaft, and it is about 2.8 miles farther to the Cherry portal, and by use of electric haulage this tunnel can probably be best built as far as Eleanor, all from the Hetch Hetchy end, and lined with concrete wholly from that portal, the workmen all living at the Hetch Hetchy dam camp, and the cement for the concrete lining taken into Hetch Hetchy, from Oakdale or some station on the Sierra Railroad, over the easy grade of the proposed new road while the temporary rails are down.



In fairly sound rock and where outside water pressure will not be excessive, amount of excavation may be lessened, and concrete lining thinned, at discretion of Engineer in charge

Note for all Tunnel Sections
All Lagging and as many Main Timbers as possible to be removed before concreting.

TYPICAL HEAVY SECTION
FROM INTAKE TO SAN JOAQUIN VALLEY
To be used thru heavy shattered rock or soft ground or where subject to high outside water pressure

TYPICAL SECTION
FROM SAN JOAQUIN TO GATE HOUSE NEAR IRVINGTON

TYPICAL SECTION FOR MINIMUM THICKNESS OF LINING
FROM INTAKE TO SAN JOAQUIN VALLEY
To be used thru sound rock where the principal use of the lining is for smoothness and to increase delivery

CONSTRUCTION QUANTITIES PER LINEAL FOOT

	Section Ⓐ		Section Ⓑ		Section Ⓒ	
	Untimbered	Timbered	Untimbered	Timbered	Untimbered	Timbered
Excavation	4.13 cu. yd.	5.04 cu. yd.	3.69 cu. yd.	4.49 cu. yd.	6.40 cu. yd.	7.40 cu. yd
* Concrete	1.04 " "	1.85 " "	0.59 " "	1.29 " "	1.60 " "	2.48 " "
Timbers	———	34 B.M.	———	32 B.M.	———	43 B.M.
Lagging	———	60 "	———	57 "	———	50 "
Bracing etc.	———	12 "	———	12 "	———	10 "

* Main Timbers assumed left standing

HYDRAULIC ELEMENTS

	Section ⒶⒷ	Section Ⓒ
Area	83.6 sq. ft.	130.0 sq. ft.
Wet Perim.	32.8 ft.	40.4 ft.
Hyd. Radius	2.55 "	3.22 "

PROPOSED PRESSURE TUNNELS
HETCH HETCHY AQUEDUCT

John R. Freeman, Consulting Engineer
Providence, R.I. July 13, '12

Description of Hetch Hetchy Aqueduct Tunnels

(125) In the early years the water for the city would be released from the Hetch Hetchy reservoir by gates in the base of the dam and flow down the natural channel for about twelve miles to a point one and a half miles upstream from the mouth of Cherry Creek, designated on the accompanying plans as the "Early Intake," at which point the present aqueduct construction is to begin. The aqueduct for substantially the entire distance down from the mountains to the edge of the San Joaquin Valley is proposed to be built of the pressure tunnel type, but with barely sufficient pressure to make sure that its section will always be filled under the various conditions of future use.

Advantage of Pressure Tunnels

(126) The pressure tunnel has great advantages over a tunnel built upon the hydraulic gradient, like the earlier aqueduct tunnels of Boston, New York and Baltimore. Its chief advantage is that it responds much more quickly to any change in rate of delivery, this taking effect with all the speed of an elastic wave instead of by the slow process of a free surface wave. This is particularly important in connection with power development. Another important advantage is found in the facility with which the rate of delivery can be largely increased by simply adding to the hydraulic gradient by means of increased pressure applied at the upstream end of the section.

Type of Tunnel Construction

(127) The cross-section of the tunnel will be varied to suit the quality of the rock. This is shown in outline in accompanying cross-section drawings. For the larger portion between the Hetch Hetchy dam and a point a few miles west from the crossing of the main Tuolumne River, firm sound rock is expected, without tendency to crush under the over-burden or to swell under atmospheric influence, and through rock of this kind almost the sole function of the concrete lining is to give greater smoothness to the waterway and so increase the delivery of a tunnel of a given size. The lining, of course, has some further advantage in tending to prevent at any future time the falling of loose rock from the roof, and it prevents escape or infiltration of water in fissured rock. The tunnel will everywhere be under only a moderate water pressure, barely sufficient to insure it being completely filled at time of greatest delivery.

All Tunnels Lined Thruout with Concrete

(128) All of these tunnels are to be smoothly lined with concrete thruout their entire length and will largely be of circular cross-sections. In this respect, they will be similar to the pressure tunnels now under construction for the water supply of the City of New York, but these will be under much smaller pressure, at much less distance below the water table of the country, and can therefore have a much thinner and less expensive concrete lining.

For that part of the tunnel in sound rock where the line has to carry no particular external stress, the section can be made of the horseshoe form, shown in the accompanying drawings, and thereby obtain a little greater area and carrying capacity for a given cost of construction per lineal foot.

Tunnel Slope and Hydraulic Gradient

(129) For twenty miles, more or less, out of the 30 miles of tunnel found in crossing beneath the Mt. Diablo range, the circular section will be mostly adhered to, because of this presenting the strongest possible form either against external water pressure or a yielding of unsound rock. The circular form also presents greater resistance to the stresses of pressure grouting, which will doubtless be followed where the rock penetrated is found seamy or water-bearing.

(130) For the purpose of economy the tunnel floor all the way from the Hetch Hetchy to the foothills is given the steep gradient of about ten feet per mile, or more precisely ten feet in five thousand feet. Ordinarily the hydraulic gradient will be only about eight feet per mile but can be increased to ten feet or even more for the purpose of increasing the delivery of the tunnels. The diameter of the tunnel all the way from the Hetch Hetchy to a point some eight or ten miles back from the edge of the San Joaquin Valley, where softer rock begins, will be approximately 10 feet in finished diameter with a net sectional area of 80 square feet. Therefore when delivering 400 million gallons daily, equivalent to 620 second feet, the mean velocity of the water flowing thru the tunnel will be 7.75 feet per second. This high velocity will be of some advantage in tending to keep the tunnel clean and free of sediment or anything that might impair its delivery, and will permit of computing its discharge with a higher co-efficient that in a more sluggish flow fed by water containing any sediment.

(131) The length of the tunnel from the Early Intake at Mile 159.6, to the edge of the San Joaquin Valley, at approximately Mile 124.1, is 34.6 miles, including in this distance two steel siphon pipes aggregating less than one mile in length at about Mile 154 crossing the South Fork and another at Mile 135, at the crossing of the main Tuolumne River near Red Mountain Bar. At about 19 miles downstream from the Early Intake occurs the one power drop on this first construction, which is from 1,300 to 1,400 feet, but while the arrangements here will be made such that a power plant can be added in future, and sketch plans and surveys for it have been made and outlined on the ground, none is

proposed to be built at the same time with the construction of the aqueduct, or within any definite period afterwards.

Description of San Joaquin Pipe

(132) The San Joaquin Valley will be crossed ultimately by two lines of steel pipe, each 7 1-2 feet in net diameter, smoothly lined with Portland cement mortar in order to give increased carrying capacity and to prevent rust, and each about 45 miles in length. The steel siphon pipes of the New York aqueduct are being thus lined and I believe that with the Portland cement we can secure the admirable durability found in Mr. Schussler's excellent wrought iron pipe at less cost and with great gain in hydraulic capacity. One of these pipes will deliver somewhat in excess of 200 million gallons daily, probably at least 240 millions under the increased head available from the slow velocity in the tunnels.

The country across which this pipe would be led is remarkably level and favorable to the construction of all the way excepting about a mile in the vicinity of the San Joaquin River, and here the construction is not at all difficult and involves no special hazard to the permanence of the work. The general specification for the steel pipes is given in the appendix.

San Joaquin River Crossing

(133) Across the marsh lands bordering the river it is proposed either to support the pipe on deep and strong concrete piers at an elevation above the highest flood level or possibly to support it upon an earth embankment built similar to the many reclamation dikes along the San Joaquin River. This will lift the pipe above any corrosive action of the alkaline mud, and be of permanent construction not subject to decay.

No wooden pile trestle supports, as in the Grunsky or Manson plan or in the present Spring Valley line across marshes, will be used anywhere on the aqueduct now proposed.

Across the main channel of the river, it is proposed to bury the pipe deeply in a dredged channel and surround it by a mass of concrete, placing the whole so low that it cannot interfere with navigation or be subject to injury by flood.

The Coast Range Tunnels

(134) Within the Tesla-Antonio section of the tunnel which crosses beneath the coast range, loss of head is of far greater importance than in the mountain section, by reason of the fact that any additional head used to force the delivery thru this Tesla-Antonio tunnel adds to the head tending to burst the steel pipe which crosses the valley. The hydraulic gradient of the tunnels thru the coast range is therefore made about two feet per mile. This calls for a finished diameter of cross-section of 130 square feet, corresponding to a diameter of about 12.8 feet.

For any considerable distance where the rock is discovered to be unsound it may be found expedient to obtain increased thickness of lining by means of a moderate reduction in the diameter of the tunnel instead of excavating the rock to a larger area, but in general the ground will have been so thoroly explored by diamond drilling that the excavation of the different formations can be made from the start, appropriate to the net section of 130 square feet. The total length of this portion of the tunnel is about 30 1-2 miles.

By an examination of the accompanying plans it will be noted that this tunnel is so located as to permit taking water into it from either of the three reservoirs projected at Calaveras, San Antonio and Arroyo Valle.

(135) There are no siphons required for crossing valleys save in the case of the Sunol Valley, which will be crossed by two steel pipes, each 9 feet in diameter, only one of which will be installed until the second pipe is added across the San Joaquin Valley.

Calaveras and Sunol Connections

(136) Probably this Tesla-Antonio or Coast Range tunnel would be built by installments, a beginning being made by constructing the section between the Sunol Valley and the Irvington gatehouse in the immediate future in order that it may serve as part of the line for bringing water from the Calaveras Reservoir to the city, and also serve for any increased supply that may be brought down from Pleasanton or gathered at Sunol.

This first section of the tunnel between the Sunol Valley and Irvington is placed at a low elevation in order that water from Calaveras and Sunol may be more readily diverted or pumped into it, and thence delivered by gravity-flow into the highest present level of the Crystal Springs Reservoir. By means of electric power that can be developed in course of the discharge from the Calaveras Dam, any surplus of Sunol and Pleasanton water could be pumped into this tunnel and thence flow by gravity into the Crystal Springs reservoir. The present estimate of cost includes a suitable intake for the Calaveras water but does not cover the cost of a pipe from the Calaveras Dam to the Sunol portal of this tunnel.

(137) Presumably the second installment of the coast range tunnel would be built to connect with the San Antonio reservoir, thereby conveying the water collected from the floods of Antonio Creek into the city by gravity flow, and a year or more later the extension to the Arroyo Valle reservoir would be begun, and the water from the Valle Reservoir taken to the city also by gravity flow before proceeding eastward from Arroyo Valle with the tunnel.

The question of whether it is worth while to stop on the way to the Hetch Hetchy for the Antonio and Valle Reservoirs is a question yet to be decided and should depend on the result of a few years of extremely careful gaugings of the run-off of the Antonio and the Valle in connection with records of the rainfall, this rainfall record and these stream gaugings to be made continuously by means of automatic recording clock-gauges; so that the effect of showers of different degrees of intensity upon the run-off can be discovered, and a closer estimate made of the flood flow available for storage than is now possible.

The Terminal Gatehouse

(138) On the hillside near Irvington the Hetch Hetchy aqueduct would terminate in a shaft and gatehouse provided with control branches looking toward San Francisco, Greater Oakland and toward San Jose, with other branches for local and irrigation use.

The Bay Head Crossing

(139) The line selected for purpose of estimate crosses the narrows at Dumbarton near to the present railroad crossing, and also near to the point where the two water mains of the Spring Valley Company have been successfully located for the past sixteen or eighteen years. An inspection of the railroad embankment across the marsh from Newark, and an inspection of the highway along the Spring Valley Company's present pipe line show that the marsh surface will easily carry an earth embankment with top above highest tides.

The surface of the mud flats exposed at low water appears to be soft, but beneath it is said to lie a hard, firm stratum of clay of such a character that after building out over the soft shores with embankments for supporting the pipe, similar to ordinary reclamation dikes, the submerged part of the crossing could be made by tunnel in this clay. I have inspected the railroad embankment over the easterly marshes and find all indications favorable for a cheap and safe crossing of marsh and channel.

For purpose of estimate, the simple and entirely prudent method has been assumed of laying this part of the pipe in a deeply dredged trench, connecting up the pipe on scows or on shore, in long sections, lining it with cement and coating its exterior with a thickness of concrete scarcely sufficient to submerge it when filled with air, then closing the ends floating the long section out into place with the aid of scows, lowering it and bolting the sections together with the aid of divers and then refilling the trench around the pipe with concrete. Various other well known methods could be employed. There is nothing particularly novel or difficult in a crossing of this kind.

A steel pipe of 6 feet 9 inches gross internal diameter, smoothly lined with Portland cement mortar 1½ inches thick down to a net diameter of 6.5 feet, would convey about 100 million gallons daily across to the high ground east of San Mateo, where it would deliver into a tunnel some four or five miles in length, communicating with the present Crystal Springs Reservoir.

This San Mateo tunnel will apparently be in easy ground and it is therefore made ten feet in diameter in order to economize the loss of head and permit the largest possible delivery thru the Bay Head pipe from the Calaveras Reservoir during the years prior to building of the aqueduct to the mountains.

Alternative Route for Bay Head Pipe

(140) A dotted line on the map of this portion of the aqueduct, shows a route on solid ground around the head of the bay, avoiding the submerged pipe of about one mile in length across the Dumbarton Narrows; but after considering the success that has attended the two smaller and thinner pipes of the Spring Valley Company and the fact that these did not suffer in the slightest degree in the earthquake of 1906 and have been continuously successful without interruption. After personally inspecting typical portions of the ground along each route, I am led to believe that the additional expense due to traversing about six or eight miles of additional distance in order to avoid a submerged crossing is not justified, and that we can now do no better than to follow nearly along the location picked out years ago by Mr. Schussler.

Distributing Aqueduct Around San Francisco Bay

(141) At first view it may not appear necessary to give the problem of distribution among the several communities any particular study in connection with the broad review of the merits of various possible projects from the Tuolumne and elsewhere, but on further study it is plain that all the various projects and sources for a new, large supply brought from a distance, should be placed for comparison on the same basis of delivering into storage reservoirs of great capacity close to the city as possible, and that delivery to the main distributing reservoirs within the city should also be considered in bringing a new water supply from the mountains. Also for the sake of completeness of the present study as an engineering problem, much thought has been given to the best arrangement of the distributing aqueducts and to a consideration of what happened in the earthquake of 1906, and what might happen again from a similar cause.

It is plain when one studies the prospects of future growth in the several communities all the way around the bay from San Francisco through San Mateo, Palo Alto, to San Jose, Milpitas, Niles, Hayward, and Greater Oakland that there is a practical certainty of large increase in the demands for water all the way around the bay, and that the main branches of the aqueduct can readily be located where local branches can be cheaply taken off from time to time, either for the purpose of domestic supply or for utilizing the surplus for irrigation and intensive farming until needed for domestic and municipal supply, and that the great level Potrero district in San Francisco will doubtless some day require large quantities of low service water for manufacturing purposes and that gravity flow without pumping should be provided for as much of the city's water supply as possible.

(142) After a somewhat hasty study of the topography, the geology and the conditions set forth in the report of the California Earthquake Commission, I have been led to believe that possibly the best type and location for the branch aqueduct leading from the Crystal Springs Reservoir to the distributing reservoirs in the heart of San Francisco and also for the branch aqueduct leading northward from the Irvington terminal gatehouse to Alameda, Oakland and Berkeley, is a pressure tunnel running along in the solid rock, beneath the crest of the ridges that run toward these points of delivery and crossing beneath San Bruno Mountain.

PRELIMINARY REPORT ON

THE GENERAL GEOLOGY ALONG THE PROPOSED LAKE CHABOT AND PENINSULA LINES OF THE SAN FRANCISCO WATER SYSTEM.

Made to JOHN R. FREEMAN, Consulting Engineer, by JOHN C. BRANNER, Consulting Geologist.

July 13, 1912.

(Compare with profiles on sheet entitled Studies for Alternative Distribution Aqueducts near San Francisco and Oakland.)

Leland Stanford Junior University.

Stanford University, Cal., July 13, 1912.

John R. Freeman, Consulting Engineer.

Sir—I have examined the geology along the line of the proposed conduit between the point where it leaves the main line near Mission San Jose and Lake Chabot, and submit the following report upon it.

The areal distribution of the rocks at the surface, as nearly as it could be worked out in the short time at my disposal, is shown on the accompanying map, which is an essential part of the report.*

Lake Chabot Branch East of the Bay of San Francisco.—Starting at the Lake Chabot end, the line is in serpentine of one kind or another to where it emerges from the hills on the north side of the town of Hayward. This material is all more or less broken and fragmentary and will probably all require timbering.

South of Hayward the tunnel enters the cretaceous (Knoxville) shale and standstone and continues in that formation to about mile 26. From mile 26 to mile 28 it will be in a phase of serpentine or along a line of contact between the serpentine and the Knoxville shales.

At mile 28 it enters the Knoxville shales again and probably continues in them to the Niles Canyon, though between 30 and 31 it may be in the Monterey shale which there lie next to the Knoxville beds.

South of the Niles Canyon the tunnel will enter the Monterey shale and continue in it for a distance of a mile or so, when it will pass into the overturned and crushed Santa Margarita sandstone in which it will continue to the junction with the main line of the conduit at mile 36.

The Difficulties of the Lake Chabot Line.—The proposed conduit from the Lake Chabot end to where it joins the main line is in two kinds of rocks, namely, serpentine of one kind or another, and in sedimentary beds. The line as now planned had an additional difficulty due to its following along lines of contact between different formations. Such places are liable to be zones of fracture and uncertainty in regard to the character of the materials to be handled.

The serpentine is much broken as a rule. Where it is exposed in road cuts and quarries it is nowhere massive, and it has the additional disadvantage of being very slippery when wet.

The cretaceous (Knoxville) beds along this section of the line are made up mostly of clay shale, usually standing at a high angle, that is from 45 degrees to 80 degrees. The dips are generally toward the northeast, so that the conduit follows along the strike of the beds wherever these beds occur. This means that the tunnels must be made endwise of the beds.

The rounded surface of the ground, the deep decomposition of the rocks, and the few hard rock exposures over the region where these cretaceous beds come to the surface, leads one to conclude that these shales will not be easy rocks to manage in the tunnels passing through them endwise, especially when their closely folded and jointed condition is taken into consideration.

RESUME OF THE ROCKS OF THE LAKE CHABOT SECTION.

From Mile	
21 to 23¾	Serpentine.
24¾ to 26	Cretaceous (Knoxville) shale and standstone.
26 to 28	Altered serpentine.
28 to 32¾	Cretaceous (Knoxville) shale and sandstone.
33¼ to 34	Tertiary (Monterey) shale.
34 to 36+	Tertiary sandstone (Santa Margarita) broken.

Totals.

Serpentine	5 miles.
Cretaceous (Knoxville) shale and sandstone	6¼ "
Tertiary (Monterey) shale	¾ "
Tertiary (Santa Margarita) sandstone	2 "

The Peninsula Line (Tunnel Aqueduct).—The hill through which the end of the tunnel passes is of jasper (½ mile), a very hard brittle rock well known in the roads and quarries about San Francisco.

Next to the south about ¾ mile of Merced lands are crossed, and at mile 5¾ comes the San Bruno sandstone, which continues through the San Bruno ridge to about mile 10. This sandstone is broken by joints and local faults.

Near 10 miles the line passes across the soft sands that fill the valley at and about Baden.

In proportion as these sands thin out, toward the south, however, the hills are made up more and more of rocks of the Franciscan series, so that at the depth proposed for the tunnel, one can confidently count on the hard rock from about mile 13½ to the end of the tunnel at mile 28½. The rocks are of the Franciscan series, but they are much broken by joints and local faults, and it seems probable that they will require much timbering. Near mile 27½ the rocks are yellow Chico sandstone at the surface, but these may not be struck in the tunnel.

RESUME OF THE ROCKS OF THE PENINSULA LINE.

From Mile	
4½ to 5	Jasper.
5 to 5¾	Merced sands.
5¾ to 10	San Bruno sandstone.
10 to 13½	Unconsolidated Merced sands.
13½ to 28½	Franciscan formation, including altered eruptives, schists and serpentines.

Totals.

Jasper	½ mile.
San Bruno sandstones	4¼ miles.
Unconsolidated sands	4¼ "
Serpentines	? "
Franciscan, altered eruptives, etc.	15 "

I should add, in regard to the geology of both lines, that the details can be given with much greater precision after we shall have had time to work them out with especial reference to the enterprise in hand.

My general impression in regard to the Lake Chabot line is that by

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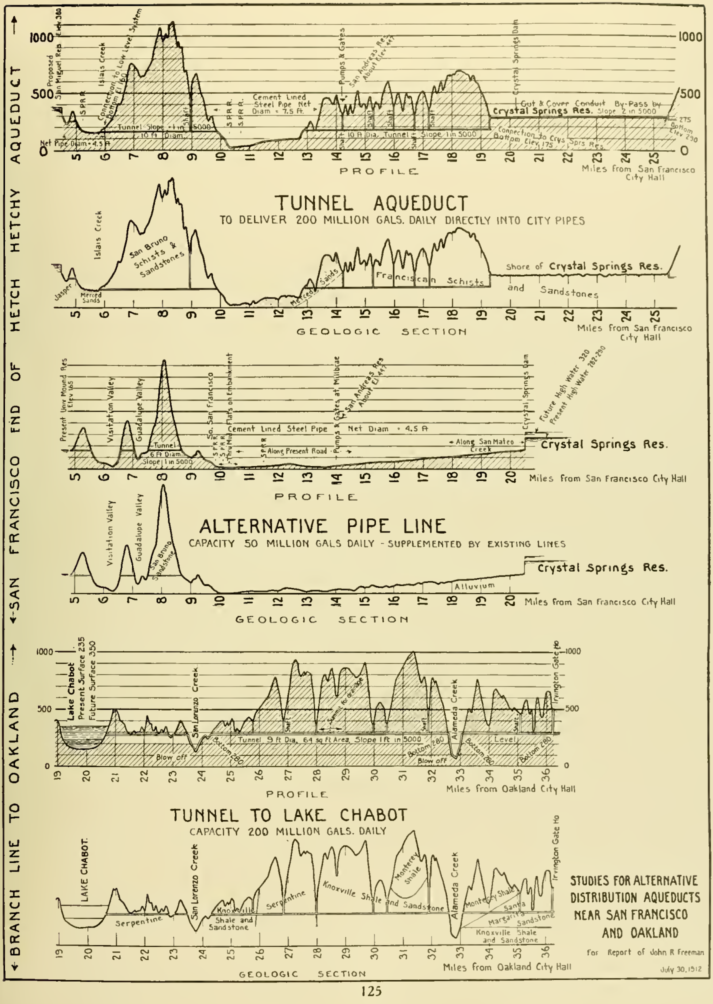
*Only the sections from this map have been reproduced. The map itself was in colors overlaid on a U. S. Geological map, and thus not available for reproduction with this report in the limited time.



← BRANCH LINE TO OAKLAND ··→
← SAN FRANCISCO END OF HETCH HETCHY AQUEDUCT →
PROFILE
Miles from San Francisco City Hall
1000
500
0
Proposed San Miguel Res. Elev. 380
S.P.R.R.
Islais Creek
Connection to Low Level System Bottom El. 160
Tunnel Slope 1 in 5000
10 Ft Diam.
Net Pipe Diam. = 4.5 Ft
Shaft
S.P.R.R.
Cement Lined Steel Pipe Net Diam = 7.5 Ft.
Pumps & Gates
San Andreas Res. About Elev. 447
10 Ft Dia. Tunnel Slope 1 in 5000
Crystal Springs Dam
Cut & Cover Conduit By-Pass by Crystal Springs Res. Slope 2 in 5000
Connection to Crys. Sprs. Res. Bottom Elev. 175
275
Bottom Elev. 290
GEOLOGIC SECTION
Jasper
Merced Sands
San Bruno Schists & Sandstones
Merced
Sands
Franciscan Schists and Sandstones
Shore of Crystal Springs Res.
Present Univ. Mound Res. Elev. 165
Visitation Valley
Guadalupe Valley
Tunnel
6 Ft Diam.
Slope 1 in 5000
So. San Francisco
S.P.R.R.
Thru Mud Flats on Embankment
Cement Lined Steel Pipe Net Diam = 4.5 Ft
Along Present Road
Pumps & Gates at Millbrae
San Andreas Res. About El. 447
Along San Mateo Creek
Crystal Springs Dam
Future High Water 320
Present High Water 282-290
Crystal Springs Res.
San Bruno Sandstone
Alluvium
Miles from San Francisco City Hall
Lake Chabot
Present Surface 235
Future Surface 350
San Lorenzo Creek
Tunnel 9 Ft Dia., 64 sq Ft Area, Slope 1 Ft in 5000
Blow off
Bottom 280
Summit for drainage
Shaft
Alameda Creek
Level
Irvington Gate Ho.
Miles from Oakland City Hall
LAKE CHABOT
Serpentine
Knoxville Shale and Sandstone
Monterey Shale
Santa Margarita Sandstone

TUNNEL AQUEDUCT

TO DELIVER 200 MILLION GALS. DAILY DIRECTLY INTO CITY PIPES

ALTERNATIVE PIPE LINE

CAPACITY 50 MILLION GALS DAILY - SUPPLEMENTED BY EXISTING LINES

TUNNEL TO LAKE CHABOT

CAPACITY 200 MILLION GALS. DAILY

STUDIES FOR ALTERNATIVE DISTRIBUTION AQUEDUCTS NEAR SAN FRANCISCO AND OAKLAND

For Report of John R Freeman

July 30, 1912

moving it half a mile to the east, from mile 24¾ to where it joins the main line, the character of the rock would, at least, have the advantage of being uniform in character, and the risks of uncertain contacts and crushed zones would be avoided.

The (original) Peninsula line passing through Colma and Ocean View, opposite about miles 8 to 12, is practically in incoherent sand. The sand across the valley floor cannot be avoided, but by making a turn at the shaft and crossing to the San Bruno mountains,* two miles of the sand can be eliminated and the line will lie otherwise in San Bruno sandstones.

Yours respectfully,

(Signed): J. C. BRANNER, Consulting Geologist.

Stanford University, Cal., July 20, 1912.

(Supplementary to the geological report of July 13, 1912.)

John R. Freeman, Consulting Engineer, San Francisco, Cal.

Dear Sir—This is supplementary to my report of July 13th upon the geology of the Peninsula line of the San Francisco water system.

The accompanying profile has the general geology shown upon it.

It is only necessary to add in regard to the so-called Franciscan rocks, in which about all of that part of the tunnel is located, that these rocks are mostly sandstones and shales more or less broken and similar to those exposed in the cuts in the San Bruno mountains south of San Francisco.

Attention is also called to the importance of caution in the exact location of the south end of the branch tunnel leading from the shaft at mile 25.3 to the Crystal Springs reservoir, owing to the fact that the south end of that tunnel ends very near the fault passing through the lake.

Yours respectfully,

J. C. BRANNER, Consulting Geologist.

It is in no way essential to our present problems to adopt tunnels for this part of the circuit. Steel pipes, built one at a time, as the cities grow, and located along the highways would serve the purpose just as well as do the present pipes and would be much cheaper than the ten-foot tunnel indicated as running beneath the ridge of rock from Irvington gatehouse to Lake Chabot, or the ten-foot tunnel from the westerly terminus of the Bay Head pipe into the Crystal Springs reservoir and the tunnel 10 feet in diameter indicated on the plan as running beneath the Buri Buri ridge from Crystal Springs and beneath San Bruno Mountain to the reservoirs in the city.

As stated above, this idea of tunnels for these portions of the line is merely a suggestion for further investigation.

(143) Another suggestion for further study relates to the feasibility of utilizing the one pressure tunnel leading from Crystal Springs reservoir to the distributing reservoirs in the city to supply water from the Crystal Springs level for, say half the day, to the city reservoirs distributing to the low service districts, and for the other half of the day use the same aqueduct for distributing water from the higher San Andreas level to the more elevated distributing reservoirs within the city limits.

It appears feasible to devise a system of gates and electrically driven centrifugal pumps, all located in the shaft or adit opposite Millbrae and leading into San Andreas, so that at some definite morning hour the gates would be set for delivery from Crystal Springs or for delivering water from the Bay Head pipe, which had not passed through Crystal Springs into the city reservoirs on the low service line, and having replenished these to their high water mark, which could be done in a very few hours by reason of the large capacity of this aqueduct, then set the gates so as to deliver from the San Andreas level into the higher distributing reservoirs.

The pumps in the same building would take either water from Crystal Springs or water from the Bay Head or Hetch Hetchy water direct from the Bay Head pipe and deliver it at will either into the storage in San Andreas or directly into the higher service reservoirs in the city. It will be seen that thus alternating the service the whole delivery of Tuolumne water by the Bay Head pipe could be taken directly into the city and deposited in the city distributing reservoirs without detention or admixture in either Crystal Springs or San Andreas, or conversely, that for any desired number of hours, after the city reservoirs had been replenished, the full supply from the Bay Head pipe could be delivered in part by gravity into Crystal Springs while the pumps lifted to the full extent of their capacity from the Bay Head pipe into San Andreas.

Crystal Springs By Pass

(144) As elsewhere suggested it will ultimately be best to deliver the Hetch Hetchy water direct from the aqueduct into the house pipes without mixing it with surface waters or exposing it in large reservoirs which hold the reserves. Therefore the plans are now drawn so that at some convenient future time a by pass can be built along the west shore of Crystal Springs Reservoir of the comparatively cheap "cut and cover" type near the high water level.

Higher Level for Lake Merced

(145) In considering the distribution of the mountain water and the disposal of the surplus that will flow by gravity without additional pumping, the thought naturally suggests itself that double the present storage reserve could be accumulated in Lake Merced by building the dam at its outlet 10 or 15 feet higher, which can be cheaply done. This would tend to decrease its natural yield by decreasing the inflow from surrounding sands and by increasing its seepage outward to the sea, but this body of water is to be regarded as a reserve rather than as a source. It is said to yield only about 3 million gallons daily. The quality would doubtless be improved by the greater depth of storage and the consequent smaller growth of aquatic plants on the bottom. Although these lakes hold 2,500 million gallons when full, which has value as a reserve against some contingency that could hardly occur more often than once in a half century, probably their chief future use will be to beautify a park, and this possibility of raising the flow line should be given attention when laying out any expensive circuit of pleasure roads around the lake.

Safety Against Earthquakes

(146) These suggested distribution tunnels each would average about half a mile distant from the great earthquake rifts of 1906 and 1868 and the location of this rift would, it is believed, thus be more of a safeguard than a danger; in fact, a sort of slip joint for the relief of stress that might otherwise occur along the aqueduct line.

The history of the structures of the Spring Valley Water Company in and near to the San Andreas rift is particularly interesting. The San Mateo dam did not suffer in the slightest degree, although it was only a few hundred feet away from the rift and parallel to it, and the rift passed directly through the shallow easterly end of the earth dam at San Andreas without spilling any water, although the reservoir was nearly full.

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*Note by J. R. F. The location has been changed following the above suggestions, and some of the distances and descriptions given in Professor Branner's report have been adjusted to the new line.

The greatest injury to the water pipes occurred where they were on or in soft ground, not far away from rock. The presence of water in the sand or gravel has apparently been an important influence and along the entire line from Hetch Hetchy to San Francisco the only points where damage is to be particularly feared in case of an earthquake as severe as any here within the historic period, are (1) over the soft ground where the steel pipe crosses the Sunol Valley, (2) in the soft ground near the San Joaquin River and (3) in the soft ground where the Bay Head pipe crosses at the base of the hills near Irvington, (4) again where it meets the slope of the hills near San Mateo, (5) where the distribution line crosses the soft ground in the valleys near San Bruno Mountain. In the steel pipe and not in the tunnels are the places where the earthquake ruptures may be feared. The steel used is very soft, tough and ductile and every one of these steel pipes is very accessible and could quickly be repaired by boiler makers or steel ship builders from stock that would always be on hand.

The Los Angeles aqueduct runs for miles parallel and near to the Owens River rift of 1878, and in the Elizabeth Lake Tunnel it crosses a part of the San Andreas rift which did not slip in 1906. Here and there the safety will be in supplies of water in storage near the city. The storage reservoirs near the cities could supply San Francisco and Oakland for a full year.

It is, I believe, commonly recognized among students of earthquake conditions that damage to structures such as those we have to consider is highly improbable except where a masonry structure, like a dam or an aqueduct, crosses a rift or active fault line or where the structures are on soft ground permeated with water. The experience along the San Andreas rift in the earthquake of 1906 is very instructive and very reassuring with regard to the safety of all the structures now under consideration.

I believe that serious dangers to any important part of the works, or such as could put them out of business long enough to threaten a water famine, are so highly improbable and so remote that they need not be further considered.

A Shorter Aqueduct Route

(147) It is plain that a much shorter route for the aqueduct from Hetch Hetchy to San Francisco could be located by crossing San Francisco harbor from Alameda to Potrero Point in water which the charts of the U. S. Coast Survey indicate is nowhere more than about 60 feet deep, and thus within range of dredging a pipe channel and the work of submarine divers in building and calking sections of pipe.

Personally, I should not have any great fear of the safety of such a line, even in earthquakes, or fear that a water famine might result from inability to make repairs within a brief time if one or all of the series of pipes in which the crossing might be made should become broken, but it is plain that any line crossing this uncertain ground would not give the popular sense of security that is desirable in an enterprise costing many million dollars and upon whose nearly continuous operation the safety of the city against water famine would largely depend. The distance from shore to shore across the harbor at the most favorable point is about six miles, but this could be shortened two miles by building a long embankment with dredged material deposited to a height well above the highest tides.

As showing that other engineers have not feared to project a crossing of this kind, attention may be called to the fact that the proponents of the McCloud River project, and those of all of the supplies proposed from the north or northeast have made use of a route across the harbor to shorten and lessen the expense of their aqueduct lines.

Nevertheless, public confidence is an asset of such great value that I have been deterred from locating the main pipe line for San Francisco along this shorter route.

Obviously, the saving in cost by and the objections to laying the main future aqueduct pipe to San Francisco across the harbor instead of around the head of the bay should be given due weight when balancing the merits of sources from the north against those from the east, whose pipes pass over the longer and perhaps safer routes.

Lengths of Hetch Hetchy Aqueduct Tunnels Compared With Those of Los Angeles Aqueduct

Since the great length of tunnels proposed in th epresent Hetch Hetchy project may cause foreboding of trouble by those unfamiliar with recent water supply developments, it is of interest to compare the lengths of tunnels and steel pipes in the project now proposed with the tunnels and pipes which have been built during the past five years in connection with the water supply of the city of Los Angeles, Cal.

The Los Angeles Aqueduct is built of the full diameter for its entire length, suitable for bringing 273 million gallons daily over a distance of 222 miles from its intake on Owens River to its terminal storage and distributing reservoir in the San Fernando Valley, which reservoir has a relation to the Los Angeles Aqueduct corresponding to that which Crystal Springs and the enlarged Lake Chabot bear to the present Hetch Hetchy plan. The distance from the Early Intake to the Crystal Springs Reservoir will be only . . . . 140. miles, as against the 235 miles for Los Angeles.

The extension tunnel from Hetch Hetchy to the Cherry Reservoir will add . . . . 6.8 miles.
and the tuture tunnel from the Early Intake to the Hetch Hetchy will add nearly . . . . 20. "

The distributing aqueduct from Crystal Springs by the tunnel line alternative and delivering into the San Miguel Reservoir, including the Crystal Springs by-pass, will add about . . . . 22.5 "
so that the total complete length from Cherry Valley Reservoir to San Miguel Reservoir, within about three miles from the San Francisco City Hall will be . . . . 189.3 "

From the Owens River Intake to the center of Los Angeles is . . . . 259. "

The tunnels of the Saugus Division of the Los Angeles Aqueduct are of the same size as those of the Tesla Division on the San Francisco project. Those of the mountain division of the Hetch Hetchy are 10 per cent smaller in area than the long Elizabeth tunnel of the Los Angeles Aqueduct. The Eleanor-Hetchy tunnels are of about the same size as the smallest on the Los Angeles Aqueduct.

The total length of tunnels on the Los Angeles project now substantially all completed, is 51.5 miles. The total on the Hetch Hetchy project between Early Intake and Crystal Springs is 65.4 miles, but the Los Angeles project contains 100 miles of concrete conduit, to which there is no counterpart on the Hetch Hetchy.

The total length of steel siphon pipes on the Hetch Hetchy project is 65.7 miles, while on the Los Angeles project it is only 9.3 miles.

The total water power that can be developed on the Los Angeles project is about 65,000 horsepower. On the Hetch Hetchy Aqueduct about 145,000 horsepower of 24-hour power can be very cheaply developed, or 200,000 horsepower at peaks.

In parallel column the comparison stands as follows:

First Installation.	San Francisco early intake to Crystal Springs.	Los Angeles Intake to San Fernando Reservoir.
	Miles.	Miles.
Unlined canal	0.0	21.14
Canal lined with concrete.	0.0	39.56
River channel utilized only in first installation	(20)	0.0
Tunnels lined with concrete.	65.4	51.50
Concrete aqueduct, cut and cover.	0.0	97.84
Concrete siphon	0.0	2.75
Steel pipe siphon	65.7	9.30
Flumes	0.0	0.17
Totals	131.1	222.26
Tunnel extension, Hetch Hetchy to Cherry. .	6.8	0.0
Future extension of tunnel in substitution for river channel, Hetch Hetchy to Early Intake	20.0	0.0
Totals	157.9	222.26
Total from intake to center of city. . . .	189.3	259.

The San Miguel Distributing Reservoir

(148) A remarkably good site for a distributing reservoir is found in the San Miguel Valley about three and one-half miles southerly from San Francisco City Hall, which with flow line at 385 feet above city base, equivalent to 393.74 above mean sea level, would contain approximately 500 million gallons, according to a survey which I have had recently made. This is five and a half times as much storage as the Spring Valley Company's nine city distributing reservoirs contain. The elevation could be made 400 feet above sea level, with increase of content to 550 million gallons.

This site possesses such remarkable merit that I recommend its purchase, and I have planned my delivery conduits to connect with this, and propose that this be taken as the delivery point in comparing the several projects.

While its elevation is appropriate to supplying the middle districts and could be worked in connection with the present Lake Honda Reservoir of the Spring Valley Company (the dam of which could be raised to a corresponding height), its value as a reserve applies to lower districts of the city as well.

This site is shown in the survey plans on the opposite page and in the accompanying photographs. The area covered by the water surface will be about 30 acres. Outside of this there should be acquired a strip of land everywhere at least 200 feet in width outside of the high water line, the inner hundred feet being grassed and the outer hundred feet occupied by the bed and sloping banks of a broad roadway built on a gradient everywhere slightly ascending the valley, and provided with very deep gutters at both sides for intercepting the drainage of the street and of the adjacent territory and carrying it to downstream from the dam.

It will be seen from the photographs that this region is at present unimproved and of small value considering its proximity, and if price is deemed satisfactory it will be advisable to procure a much broader area than the 200 feet outside the flow line above mentioned and to reforest the slopes and make this reservoir the central feature in a park. The ledge should be sluiced bare of earth all around the margin, well down toward the bottom, and the material used in making the dam uncommonly thick. The abundant hard rock will provide material for ample rockfill footings for the slopes, also for riprap and concrete. This stripping of the bedrock sides would not only add to the appearance of the reservoir and enlarge its capacity, but would lessen the tendency to aquatic vegetation, to which reservoirs with earth banks are liable under the California sun.

From the note on the plan it will be seen that with the flow line at elevation 385, this would contain a quantity of water equal to thirteen and one-half days' consumption at the present rate, and ample to meet any ordinary emergency or interruption of delivery to the city from aqueduct or pipes. It can be fed by gravity from San Andreas Reservoir like the Honda Reservoir.

As elsewhere stated I would propose that the pure mountain water be exposed in open reservoirs to the smallest extent practicable. It is not impossible that it may ultimately prove wise to provide small covered reservoirs of capacity only sufficient to equalize the variations of draft from hour to hour during the week.

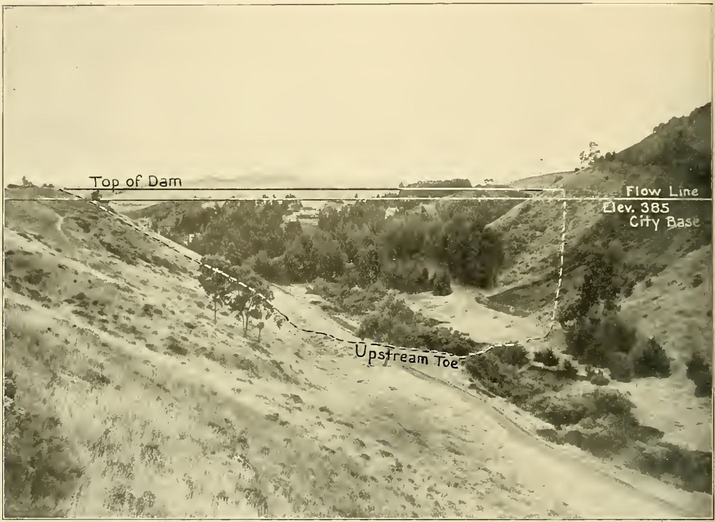
It would be possible to deliver the Hetch Hetchy water by gravity to fill this reservoir, with no important change in the aqueduct other than adding somewhere between an eighth of an inch and a sixth of an inch in thickness to the steel pipes across the San Joaquin Valley and across the head of San Francisco Bay, and moving the Crystal Springs cut and cover by-pass a little higher up the side of the hill, all of which would add about $1,550,000, or would add between 4 and 5 per cent to the entire cost of the Hetch Hetchy project.

I have not had time to fully consider this matter of a gravity supply to the San Miguel Reservoir in all of its bearings. It would give an abundance of the Hetch Hetchy water to all parts of San Francisco below the 300-foot contour, comprising more than nine-tenths of the area at present populated, and would thus permit all the present large pumping engines to be stopped and would probably call for no large additional pumping engines in the future, and the sum thus saved would probably pay good interest on the added cost. Possibly the small quantity on the higher levels could be raised by water motor pumps driven by the larger supply released to the low service districts.

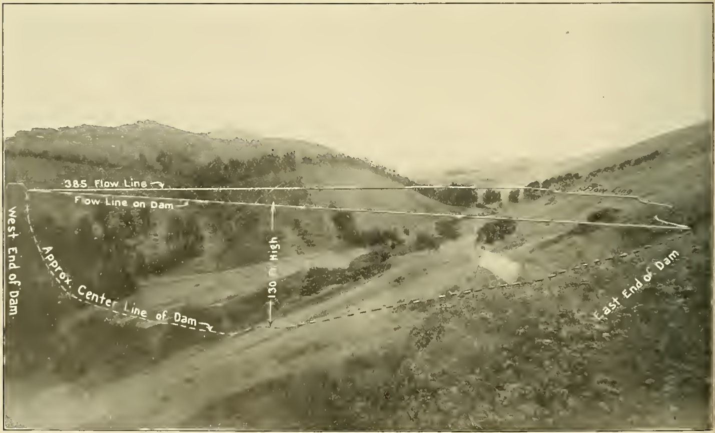
With a gravity supply of Hetch Hetchy water, and with no expense for pumping, the rule would be in San Francisco as in Boston, to supply the better water and keep the poorer water in reserve for emergencies or extra dry years.

The doubt about bringing the whole supply to the San Miguel or Lake Honda level comes in part from regarding all of these large open reservoirs within the city limits as merely reserves for accidents, and not as a part of the circulation.

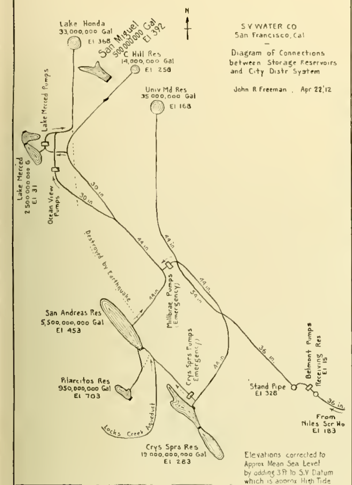
It am not yet certain if this change would be worth its cost. This matter should be more fully worked out in the final plans. The aqueducts and their hydraulic gradients as presented in the sections on pages 112 to 117 had delivery to the future higher level of Crystal Springs Reservoir, as their objective point.



DAM SITE FOR THE PROPOSED SAN MIGUEL RESERVOIR, LOOKING DOWNSTREAM.
With camera set on point of rocks at east end of line B on contour map, with lens at about elevation 365.



LOWER END OF THE PROPOSED SAN MIGUEL RESER VOIR, LOOKING UPSTREAM FROM NEAR DAM SITE.
Camera set about 20 feet south from east end of dam, slightly above flow line.

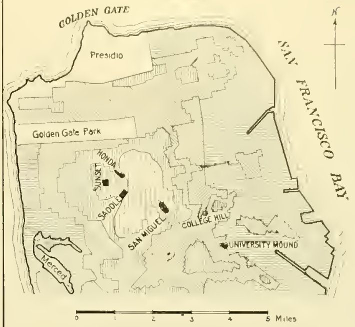


S V WATER CO
San Francisco, Cal

Diagram of Connections between Storage Reservoirs and City Distr System

John R Freeman, Apr 22,'12

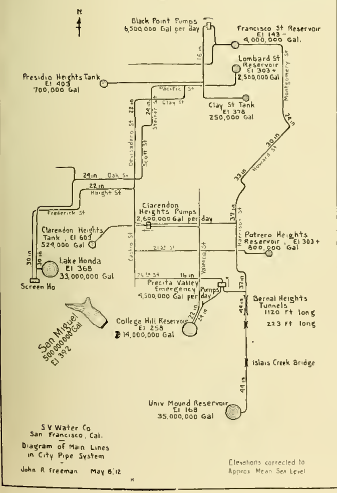
Elevations corrected to Approx Mean Sea Level by adding 3 ft to S.V Datum which is approx High Tide



	Name of Reservoir	Appr Elev	Capacity Mil Gal	District Supplied	Acres in District	Designation
	University Mound	168	37	▤	8567	Low Service
	College Hill	258	14	▨	1600	Middle Service
	Honda & Miguel	392	550	▒	8147	High Service
Proposed	Saddle	513	55	▥	4354	Hill Service
	Sunset	723	15	▥	1400	Extra High Service

Elevations above Mean Sea Level

Study of Relation of Elevation of Reservoirs to Districts Supplied with particular reference to Reserve for Emergencies in Proposed San Miguel Res.

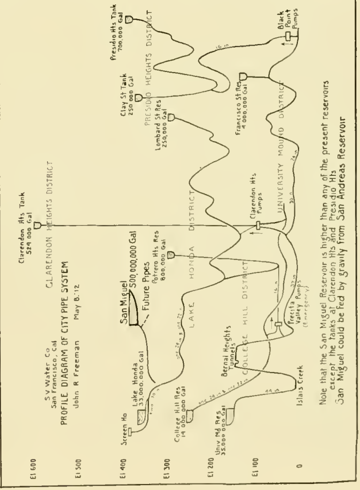


S V Water Co
San Francisco, Cal.

Diagram of Main Lines in City Pipe System

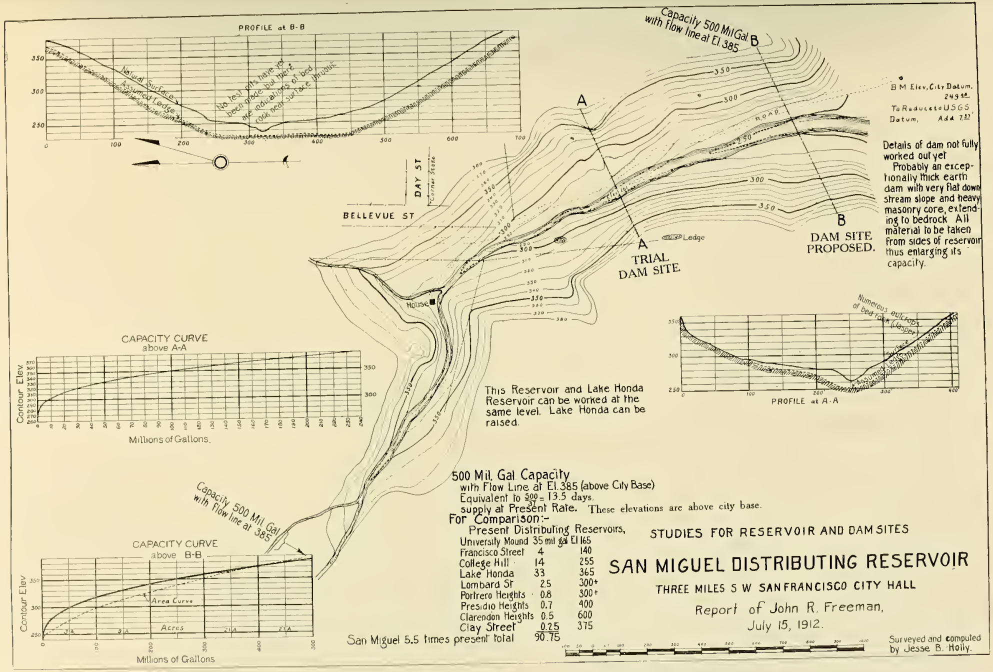
John R Freeman May 8,'12

Elevations corrected to Approx Mean Sea Level



S V Water Co
San Francisco, Cal
PROFILE DIAGRAM OF CITY PIPE SYSTEM
John R Freeman May 8,'12

Note that the San Miguel Reservoir is higher than any of the present reservoirs except the tanks at Clarendon Hts and Presidio Hts
San Miguel could be fed by gravity from San Andreas Reservoir



Details of dam not fully worked out yet

Probably an exceptionally thick earth dam with very flat down stream slope and heavy masonry core, extending to bedrock. All material to be taken from sides of reservoir thus enlarging its capacity.

This Reservoir and Lake Honda Reservoir can be worked at the same level. Lake Honda can be raised.

500 Mil. Gal Capacity
with Flow Line at El. 385 (above City Base)
Equivalent to $\frac{500}{37}$ = 13.5 days.
supply at Present Rate. These elevations are above city base.

For Comparison:-
Present Distributing Reservoirs,

University Mound	35 mil gal	El 165
Francisco Street	4	140
College Hill	14	255
Lake Honda	33	365
Lombard St	2.5	300+
Portrero Heights	0.8	300+
Presidio Heights	0.7	400
Clarendon Heights	0.5	600
Clay Street	0.25	375
San Miguel 5.5 times present total	90.75	

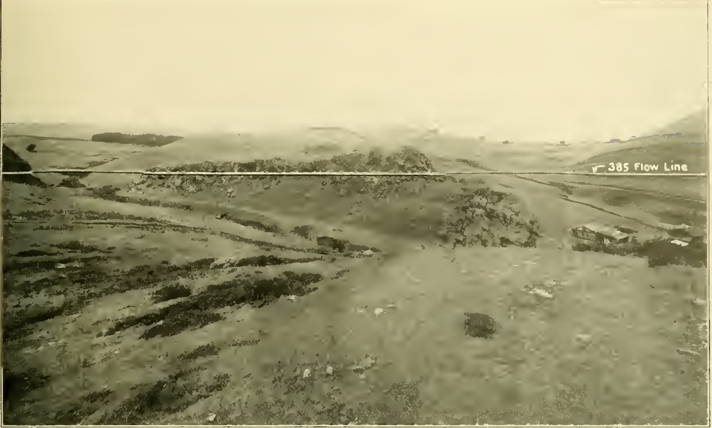
STUDIES FOR RESERVOIR AND DAM SITES

SAN MIGUEL DISTRIBUTING RESERVOIR

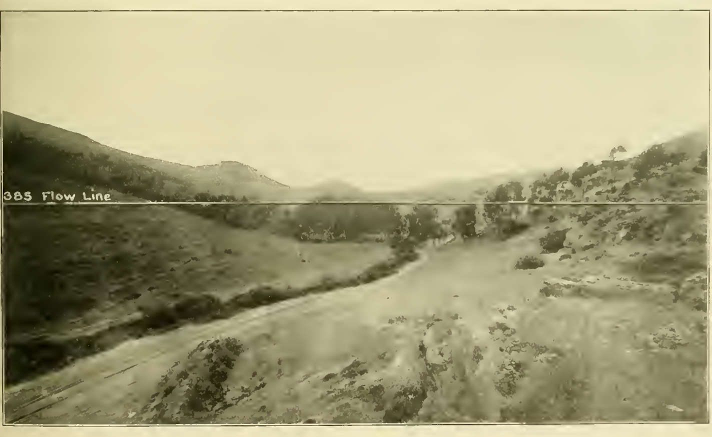
THREE MILES S W SAN FRANCISCO CITY HALL

Report of John R. Freeman,
July 15, 1912.

Surveyed and computed
by Jesse B. Holly.



UPPER END OF THE PROPOSED SAN MIGUEL RESERVOIR, LOOKING UPSTREAM.
Camera lens at about 10 feet above flow line 385. The extreme wide angle short focus lens used lessens the apparent angle between the two small valleys.



VIEW LOOKING UP THE SITE OF THE PROPOSED SAN MIGUEL RESERVOIR.
Camera lens at about 10 feet below flow line, from same point B as view of dam site, but looking in nearly the opposite direction.

Increasing of Capacity of Lake Chabot

(149) The matter of providing a great reserve of water sufficient for the most serious accident to the aqueducts, also sufficient for tiding over domestic consumption during a period of two or three years of rainfall more severe than has ever been observed in California, has received my careful study for a long time past, and I have devised what I believe a fortunate solution in raising the dam on San Leandro Creek by which Lake Chabot was created, so as to increase its depth of storage by 115 feet, thus making the total contents of the lake sufficient to supply nearly 100 million gallons daily for an entire year without inflow meanwhile.

The location of this great reservoir in its relation to the cities of Berkeley, Alameda, Oakland, etc., is even better than that of the great Crystal Springs storage reserve in its relation to San Francisco, and it is a pleasant surprise to find how cheaply this vast quantity of storage can be provided. The cost per acre foot is found to be less than that which has been often incurred in Colorado, for example, for storage solely for the purpose of irrigation.

Safety of the High San Leandro Dam

(149a) The conditions as regards safety of such a high earth dam on this location are found apparently all that could be desired, although we have not yet made any diamond drill borings or test pits on the site. Bedrock crops out at various points at both ends of the present dam, and the Chief Engineer of the People's Water Company tells me that bedrock exists entirely across the gorge beneath the present dam. A large quarry operated a very few hundred yards distant, on the adjacent hill high above the level of the present dam, gives proof of the substantial character of the bedrock formation and the opportunity for quarrying rock at a very low cost per cubic yard is so uncommonly good that I have included the depositing of an immense amount of this on top of the downstream slope of the proposed dam, more for its psychological effect on the public than for any sound engineering reason.

Outline plans are presented, and it will be noted that in deference to its proximity to a populous region I have made the dam far thicker and with flatter slopes than are common, and have given it an uncommon core wall for safety against possibility of burrowing animals. The details of a rough preliminary estimate of the cost of this dam are presented below.

I am told that in times of heavy rain considerable silt or turbidity comes into the upper end of the present San Leandro Reservoir. This could be diverted by means of a small dam near the head and either held back pending subsidence or could be diverted by tunneling.

The water from the Hetch Hetchy would be delivered into this reservoir by force of gravity.

Cost of Raising Dam

(150) The total cost has been estimated at about $3,000,000 by Mr. George T. Prince, formerly Chief Engineer of the Denver Union Water Company and who for some years past has specialized in the construction of reservoirs for irrigation purposes in Colorado.

ESTIMATE OF COST OF DAMS FOR INCREASING STORAGE CAPACITY OF LAKE CHABOT

By Raising Its Flow Line 115 Feet to About Elevation 350 Feet above Sea Level.

(New structure to be built on top of and upstream from present dam.)

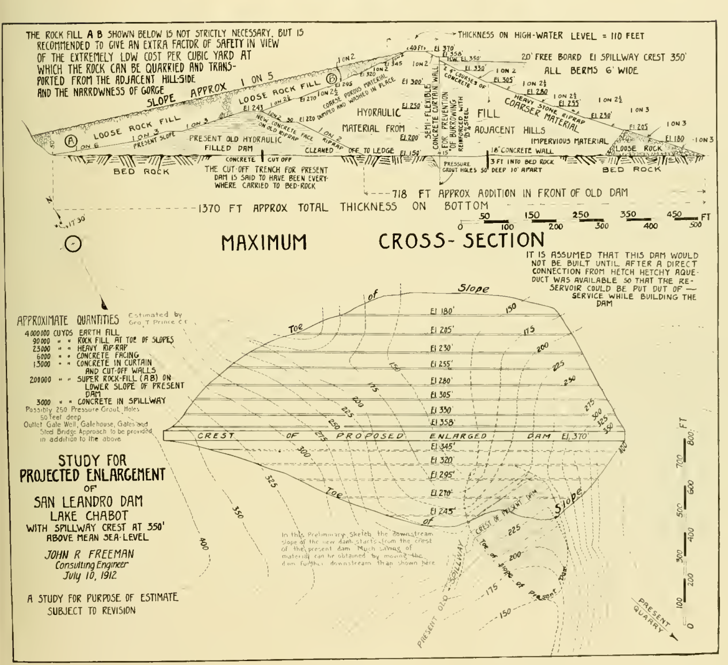
(Prepared by Geo. T. Prince, C. E., June and July, 1912.)

4,000,000 cubic yards excavation (including allowance of 10 per cent for shrinkage), at 33 1-3 cents	$1,330,000
13,000 cubic yards concrete in curtain and cut-off walls, including steel reinforcement, at $15.00	195,000
200,000 cubic yards rock filling, in place on lower slope of present dam, at $1.00	200,000
6,000 cubic yards concrete facing, laid in two 4-inch courses, including steel reinforcement, at $15.00	90,000
36,000 cubic yards rip-rap, hand placed, at $2.00	72,000
90,000 cubic yards rock filling at toe of slopes, at $1.33	120,000
250 pressure grout holes, 50 feet deep	20,000
Outlet gate well, gate house, gates and steel bridge approach	30,000
Spill-way and protection	100,000
	$2,157,000
Engineering, superintendence and incidentals	216,000
Total estimated cost of enlarged dam	$2,373,000
CASTRO VALLEY DIKE.	
500,000 cubic yards excavation (including allowance of 10 per cent for shrinkage), at 33 1-3 cents	$167,000
5,000 cubic yards of concrete in two curtain walls (including steel reinforcement), at $15.00	75,000
4,000 cubic yards concrete facing, laid in two 4-inch courses, including steel reinforcement, at $15.00	60,000
100,000 cubic yards rock fill about toe of slopes, at $1.50 per cubic yard	150,000
200 pressure grout holes, 50 feet deep	15,000
Inlet gate chamber and gates	10,000
	$477,000
Engineering, superintendence and incidentals	48,000
Total estimated cost of Castro Valley dike	525,000
Grand total	$2,898,000

Regarding Completeness of Studies of Present Project

(151) The various construction problems of bringing water from the Hetch Hetchy Valley to the cities of San Francisco, Oakland, etc., have at the present time been worked out with about as much detail as were those of the Boston Metropolitan Supply, New York Catskill Mountain supply or the Los Angeles Aqueduct, prior to the city and State legislation which fully authorized those works and definitely committed the cities to constructing them.

SITE OF CASTRO VALLEY DIKE, LOOKING TOWARD LAKE CHABOT.



THE ROCK FILL A B SHOWN BELOW IS NOT STRICTLY NECESSARY, BUT IS RECOMMENDED TO GIVE AN EXTRA FACTOR OF SAFETY IN VIEW OF THE EXTREMELY LOW COST PER CUBIC YARD AT WHICH THE ROCK CAN BE QUARRIED AND TRANSPORTED FROM THE ADJACENT HILL-SIDE AND THE NARROWNESS OF GORGE

THE CUT-OFF TRENCH FOR PRESENT DAM IS SAID TO HAVE BEEN EVERYWHERE CARRIED TO BED-ROCK

MAXIMUM CROSS-SECTION

IT IS ASSUMED THAT THIS DAM WOULD NOT BE BUILT UNTIL AFTER A DIRECT CONNECTION FROM HETCH HETCHY AQUEDUCT WAS AVAILABLE SO THAT THE RESERVOIR COULD BE PUT OUT OF SERVICE WHILE BUILDING THE DAM

APPROXIMATE QUANTITIES Estimated by Geo. T. Prince C.E.

4000000	CU YDS	EARTH FILL
90000	" "	ROCK FILL AT TOE OF SLOPES
23000	" "	HEAVY RIP-RAP
6000	" "	CONCRETE FACING
13000	" "	CONCRETE IN CURTAIN AND CUT-OFF WALLS
200000	" "	SUPER ROCK-FILL (AB) ON LOWER SLOPE OF PRESENT DAM
3000	" "	CONCRETE IN SPILLWAY

Possibly 250 Pressure Grout Holes 50 feet deep

Outlet Gate Well, Gatehouse, Gates and Steel Bridge Approach to be provided in addition to the above

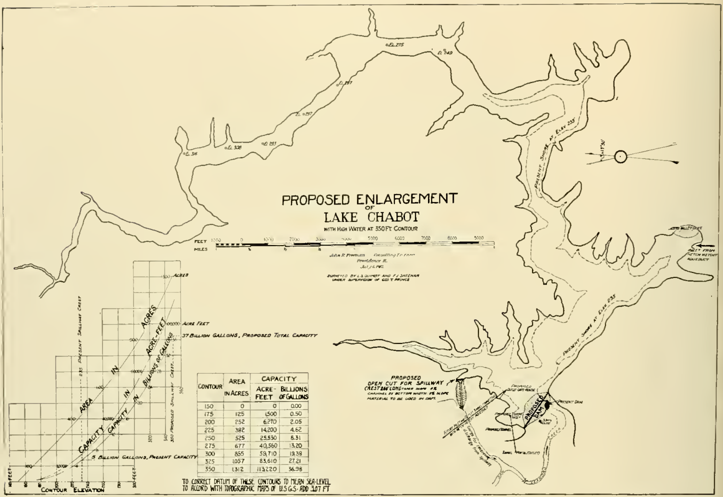
STUDY FOR
PROJECTED ENLARGEMENT
OF
SAN LEANDRO DAM
LAKE CHABOT
WITH SPILLWAY CREST AT 350'
ABOVE MEAN SEA-LEVEL

JOHN R FREEMAN
Consulting Engineer
July 10, 1912

A STUDY FOR PURPOSE OF ESTIMATE
SUBJECT TO REVISION

In this Preliminary Sketch the downstream slope of the new dam starts from the crest of the present dam. Much saving of material can be obtained by moving the dam further downstream than shown here

SLOPE APPROX 1 ON 5
LOOSE ROCK FILL
A
B
1 ON 6
1 ON 3 PRESENT SLOPE
1 ON 3
1 ON 2½
1 ON 2
El 243
El 270
El 295
El 320
El 345
El 220
NEW CONCRETE FACE ON OLD RIPRAP
COARSE POROUS MATERIAL DUMPED AND WASHED IN PLACE
PRESENT OLD HYDRAULIC FILLED DAM
CLEANED OFF TO LEDGE
CONCRETE CUT OFF
BED ROCK
THICKNESS ON HIGH-WATER LEVEL = 110 FEET
40 FT
El 370'
El 358'
H.W. El 350'
El 330'
El 305'
El 300'
El 280
El 255
El 250'
El 230'
El 205
El 200'
El 180
El 150'
20' FREE BOARD El SPILLWAY CREST 350'
ALL BERMS 6' WIDE
HYDRAULIC FILL MATERIAL FROM ADJACENT HILLS
SEMI-FLEXIBLE CONCRETE CURTAIN WALL FOR PREVENTION OF BURROWING REINFORCED WITH ½% STEEL
2 4" COURSES OF CONCRETE
HEAVY STONE RIPRAP
COARSER MATERIAL
IMPERVIOUS MATERIAL
LOOSE ROCK
15'
18" CONCRETE WALL
3 FT INTO BED ROCK
PRESSURE GROUT HOLES 50' DEEP 10' APART
718 FT APPROX ADDITION IN FRONT OF OLD DAM
1370 FT APPROX TOTAL THICKNESS ON BOTTOM
0 50 100 150 200 250 300 350 400 450 500 FT
N
17° 30'
Toe of Slope
CREST OF PROPOSED ENLARGED DAM El 370'
El 345'
El 320'
El 295'
El 270'
El 245'
CREST OF PRESENT DAM
Toe of Slope of Present Dam
PRESENT OLD SPILLWAY
PRESENT QUARRY
150
175
200
225
250
275
300
325
350
400
0 100 200 300 400 500 600 700 800 FT

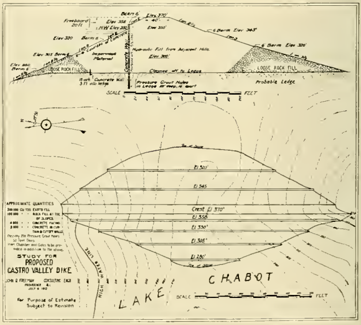

PROPOSED ENLARGEMENT
OF
LAKE CHABOT
WITH HIGH WATER AT 350 FT. CONTOUR
FEET
MILES
John R. Freeman Consulting Engineer
Providence R.
July 6 1912
SURVEYED BY L. S. QUIMBY AND F. J. SHEEHAN
UNDER SUPERVISION OF GEO. T. PRINCE
PRESENT SHORE AT ELEV. 235
PROPOSED OPEN CUT FOR SPILLWAY
PROPOSED DAM
PRESENT DAM
INLET FROM HETCH HETCHY AQUEDUCT
ACRES
ACRE FEET
37 BILLION GALLONS, PROPOSED TOTAL CAPACITY
5 BILLION GALLONS, PRESENT CAPACITY
AREA IN ACRES
CAPACITY IN ACRE-FEET
CAPACITY IN BILLIONS OF GALLONS
235 PRESENT SPILLWAY CREST
350 PROPOSED SPILLWAY CREST
CONTOUR ELEVATION

CONTOUR	AREA IN ACRES	CAPACITY	
		ACRE-FEET	BILLIONS OF GALLONS
150	0	0	0.00
175	125	1,500	0.50
200	252	6,270	2.05
225	382	14,200	4.62
250	525	25,530	8.31
275	677	40,560	13.20
300	855	59,710	19.38
325	1057	83,610	27.21
350	1312	113,220	36.98

TO CORRECT DATUM OF THESE CONTOURS TO MEAN SEA-LEVEL TO ACCORD WITH TOPOGRAPHIC MAPS OF U.S.G.S. ADD 3.07 FT

5.

LOOKING TOWARD SITE OF THE CASTRO VALLEY DIKE, FROM LAKE CHABOT



APPROXIMATE QUANTITIES
340 000 CU YDS EARTH FILL
100 000 " " ROCK FILL AT TOE OF SLOPES
4 000 " " CONCRETE FACING
3 000 " " CONCRETE IN CURTAIN & CUTOFF WALLS
Possibly 250 Pressure Grout holes 50 feet Deep
Inlet Chamber and Gates to be provided in addition to the above.

STUDY FOR
PROPOSED
CASTRO VALLEY DIKE

JOHN R. FREEMAN CONSULTING ENGR
PROVIDENCE R.I.
JULY 6 1912

For Purpose of Estimate
Subject to Revision

COMPARISON OF PROJECT NOW PROPOSED WITH THOSE PREVIOUSLY PROPOSED.

Plans of Development Upon Which the Garfield Permit Was Based

(152) The Garfield Permit of May 11, 1908, and substantially all of the recent public discussion are based upon carrying out the plan devised in 1901 and 1902, by Mr. C. E. Grunsky, then City Engineer, and a modification thereof by Marsden Manson, City Engineer, in 1908, which differed little from the Grunsky plan, save in its proposal to first build the dam at Lake Eleanor as per the Garfield Permit, and also to build a diverting dam higher up on Cherry Creek and a canal into the Eleanor Reservoir, before building any dam or other structure at the Hetch Hetchy site, Mr. Manson's modification contemplating as directed by the Secretary of the Interior, the development of this Hetch Hetchy site only when the growth of San Francisco and its neighboring cities should demand a larger water supply than could be satisfied by adding Eleanor and Cherry to the present sources.

Changed Conditions of Today

(153) Since the date of Mr. Grunsky's studies of 1901 and 1902 the problem of a new water supply has been greatly broadened by the growth of San Francisco and by the expressed desire of the rapidly growing cities of Oakland, San Mateo and Berkeley, and of other communities about the bay to join with San Francisco in the development of the Hetch Hetchy, Eleanor and Cherry sources, and the citizens and city officials of San Francisco have shown their earnestness and good faith in the matter, by increasing their water rights holdings through the recent purchase of the Cherry Creek water rights, so that in addition to owning most of the floor of the Hetch Hetchy Valley by purchase from early settlers, they now own the water rights and reservoir sites in the Eleanor and Cherry Valleys; for all of which they have paid in excess of one and a quarter millions of dollars.

Also, meanwhile San Francisco has awakened to its many opportunities, and quickened by thought of what the Panama Canal means in its future, a stronger spirit of civic pride and enterprise has been aroused.

Also within the ten years since the Grunsky plan, an example of the rational solution of a similar problem has been shown Californians in the working out of the problem incident to bringing a distant mountain supply of 420 second-feet, equal to 275 million gallons daily, to Los Angeles. Also Greater New York has solved its problems of a supply by an aqueduct largely in pressure tunnels, 90 miles from the Catskill Mountain region since the date of the Grunsky report, and at both Los Angeles and New York the work is now nearing completion.

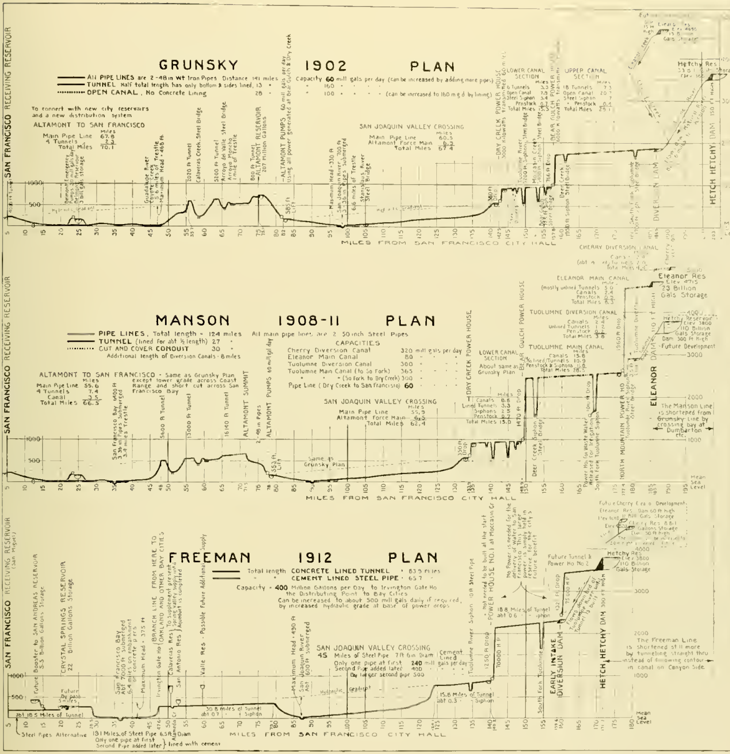
Now that Seattle, Portland and Los Angeles, the commercial rivals of San Francisco, have each built their aqueducts to distant mountain watersheds devoid of population, the thoughts of San Franciscans would naturally turn to a mountain source of soft water, and would do so although a large supply additional of hard water from underground were abundant.

Although not hard enough to curdle soap in the hand washbasin or bathtub, the present water supply furnished San Francisco is about five times as hard as that of the Hetch Hetchy would be, and would become still more hard with a larger proportion of ground water taken from the Livermore Valley, and while I have no reason to doubt that the surface waters from the peninsula watersheds are about as good as the best large unfiltered surface supplies in the United States, and I believe their catchments guarded against pollution by the Spring Valley Water Company better than in any other case that I can recall, it is certain that the Hetch Hetchy water will be better, softer, purer and more free from micro organisms. We have no sure ground for claiming it more healthful, but it will doubtless be more palatable.

There is ample proof that San Franciscans and their associates around the bay are ready today to act on broader lines in this matter than were deemed expedient ten years ago, and first of all it is proposed to buy the present works.

Perhaps it may be proper to add a personal word for showing the different point of view with which the present designer has approached the problem, because of the radical difference in the design that he submits. He had been a member of the Metropolitan Water Board of Boston, which was charged with somewhat similar problems in building works adapted for progressive future expansion, was a member of the Board of Consulting Engineers which reported upon the Los Angeles Aqueduct, and made the estimates of cost upon which its construction was financed, and on that work had seen a new light in the special need of securing ample water rights for the long future in a region where irrigation and intensive farming are practiced and where the supply of irrigable land exceeds the water available for irrigation. His preference for pressure tunnels is in part due to studies and experience gained as Consulting Engineer to the City of New York in planning its additional water supply, in which the use of the pressure tunnel has been developed to a larger extent than ever before, and he has happened to be brought into the problems of high masonry dams in such a way as to make it plain that a dam even 350 feet high, or more than twice as high as that originally proposed for the Hetch Hetchy involves no important difficulties. He offers no criticism of the former plans. Things move fast now-a-days and in ten years' time the state of the art of water supply has advanced and the San Francisco problem has broadened.

COMPARISON OF PLANS, 1902 TO 1912


GRUNSKY 1902 PLAN
ALL PIPE LINES are 2-48in Wt Iron Pipes Distance 141 miles
TUNNEL Half total length has only bottom & sides lined, 13
OPEN CANAL, No Concrete Lining 28
Capacity 60 mill gals per day (can be increased by adding more pipes)
160
100 (can be increased to 160 m g d by lining)
To connect with new city reservoirs and a new distribution system
ALTAMONT TO SAN FRANCISCO
Main Pipe Line 67.8
4 Tunnels 2.3
Total Miles 70.1
SAN JOAQUIN VALLEY CROSSING
Main Pipe Line 60.5
Altamont Force Main 6.9
Total Miles 67.4
LOWER CANAL SECTION
UPPER CANAL SECTION
ALTAMONT RESERVOIR 207 Million Gallons
ALTAMONT PUMPS
DRY CREEK POWER HOUSE
BEAR GULCH POWER HOUSE
Hetchy Res
HETCH HETCHY DAM
SAN FRANCISCO RECEIVING RESERVOIR
MILES FROM SAN FRANCISCO CITY HALL
Mean Sea Level
MANSON 1908-11 PLAN
PIPE LINES, Total length = 124 miles
All main pipe lines are 2 50 inch Steel Pipes
TUNNEL (lined for abt ½ length) 27
CUT AND COVER CONDUIT 30
Additional length of Diversion Canals = 8 miles
CAPACITIES
Cherry Diversion Canal 320 mill gals per day
Eleanor Main Canal 80
Tuolumne Diversion Canal 300
Tuolumne Main Canal (to So Fork) 365
(So Fork to Dry Creek) 300
Pipe Line (Dry Creek to San Francisco) 60
ALTAMONT TO SAN FRANCISCO - Same as Grunsky Plan except lower grade across Coast Range and short cut across San Francisco Bay
Main Pipe Line 55.6
4 Tunnels 7.4
Canal 3.5
Total Miles 66.5
SAN JOAQUIN VALLEY CROSSING
Main Pipe Line 55.9
Altamont Force Main 6.5
Total Miles 62.4
ALTAMONT SUMMIT
ALTAMONT PUMPS
CHERRY DIVERSION CANAL
ELEANOR MAIN CANAL
Eleanor Res Elev 4715 23 Billion Gals Storage
TUOLUMNE DIVERSION CANAL
TUOLUMNE MAIN CANAL
Hetchy Reservoir Elev 3800 110 Billion Gals Storage Dam 300 ft High
Future Development
NORTH MOUNTAIN POWER HO
ELEANOR
The Manson Line is shortened from Grunsky Line by crossing bay at Dumbarton etc.
FREEMAN 1912 PLAN
Total length CONCRETE LINED TUNNEL 83.9 miles
CEMENT LINED STEEL PIPE 65.7
Capacity = 400 Million Gallons per Day to Irvington Gate Ho the Distributing Point to Bay Cities
Can be increased to about 500 mill gals daily if required, by increased hydraulic grade at base of power drops
SAN JOAQUIN VALLEY CROSSING
45 Miles of Steel Pipe 7 ft 6 in Diam Cement Lined
Only one pipe at first 240 mill gals per day
Second Pipe added later 400
By larger second pipe 500
Booster to SAN ANDREAS RESERVOIR 5.5 Billion Gallons Storage
CRYSTAL SPRINGS RESERVOIR 22 Billion Gallons Storage
BRANCH LINE FROM HERE TO OAKLAND AND OTHER BAY CITIES
POWER HOUSE NO. 1 at Moccasin Cr
No Power is needed for the delivery of Water to San Francisco. This large power is simply held in reserve for the city's future benefit
Future Tunnel & Power Ho No 2
EARLY INTAKE DIVERSION DAM
HETCH HETCHY DAM 300 ft High
Hetchy Res Elev 3800 110 Billion Gals Storage
The Freeman Line is shortened at 11 more by tunneling straight thru instead of following contour in canal on Canyon Side
abt 18.5 Miles of Tunnel
30.8 miles of Tunnel
15.8 Miles of Tunnel
18.8 Miles of Tunnel
191 Miles of Steel Pipe 6.5 ft Diam Only one pipe at first Second Pipe added later lined with cement
Steel Pipes Alternative
MILES FROM SAN FRANCISCO CITY HALL

(154) BECAUSE OF THE RELATION OF THE SO-CALLED GARFIELD PERMIT TO THE EARLIER PLANS, IT IS VERY IMPORTANT TO MAKE PLAIN THE DIFFERENCES BETWEEN THE PROJECT OF TEN YEARS AGO AND THAT PRESENTED TODAY. THE PLAN OF TEN YEARS AGO IS WHOLLY UNSUITABLE TODAY.

The Garfield Permit is not broad enough for present needs.

A study of the plan of 1902 is also very instructive for illustrating the difficulty of keeping down the relative cost on a small-sized development in a rough country, and the expedients that an engineer is forced to adopt in keeping the total cost within limits on a 60-million-gallon daily project from a source 170 miles away.

It costs relatively little more to drive a tunnel for 400 million gallons daily than for 60 million gallons daily. The minimum size and cost for a long aqueduct tunnel is determined by room for railroad track and space for workmen, not by the volume of water.

Differences Between the Present Plan of Development and the Grunsky Plan of 1901-02

(155) The two plans are radically different as is natural from the fact that the present plan provides for a metropolitan water district comprising substantially all of the communities around San Francisco Bay and brings 240 million gallons daily of water from the Hetch Hetchy with its first installation, and makes 400 million gallons available daily by simply adding a second pipe, whereas the plan of ten years ago provided for San Francisco alone and brought in only 60 million gallons daily.

Considering first the division east of the San Joaquin Valley. The plan of ten years ago went first to the Hetch Hetchy and proposed building there a dam of about 150 feet in height above the lower valley floor, and letting the water flow down the natural channel of the river about sixteen miles to a point some three miles farther down than the "Early Intake" of the present plan, and from that point the water was to be carried to the edge of the San Joaquin Valley mostly in a series of open canals. These canals which followed the winding contour of the steep or precipitous canyon side for a total length of about 28.6 miles, with which was included an additional length of about 10.6 miles of tunnel and 5.2 miles in siphon pipes or penstocks, a total distance of 44.4 miles.

The present project covers all of this distance by tunnels in bedrock, all completely lined with concrete. All of the tunnels of the present project have 400 to 500 million gallons daily capacity with only 0.9 mile of siphon pipe of equal capacity. The Grunsky siphons were of only 60 million gallons daily capacity, each composed of a pair of 4-foot iron pipes supported by a steel bridge over the stream. The present plan carries its siphons on concrete piers or arches.

Tunnels in Plan of 1902

(156) Mr. Grunsky's 10.5 miles of tunnels east of the San Joaquin were assumed to be through hard rock, of which but little was expected to require top arch lining, although they were to be floored with concrete and their sides lined with concrete for smoothness. The clear width of these tunnels was to be 7.5 feet and their center height 9 feet, thus accommodating an additional supply of water from a future enlargement of the capacity of the canal, which was to be built of only 150 second feet capacity at first and to have a fall of four feet per mile. His open canyon-side canal was to be put into service without lining either the bottom or the sides, but it was suggested that later a lining of concrete six inches thick on bottom and sides, without increase of excavation, would so smooth up the bed as to increase the carrying capacity from 150 second feet to over 250 second feet. The cost of this 6-inch concrete lining was not included.

The present tunnels carry everywhere 620 second-feet from the start, with opportunity for 25 per cent increase by applying more pressure at the head.

(157) In the Grunsky plan the rainwater accumulating on the hillsides above the open canal notched into the canyon side, was to be intercepted by small ditches, carried under the canal by culverts or carried across the top if more convenient. It was planned to arrange the canal inlet so that when the river was turbid the canal system could at once be put out of service, and downstream from the headgate a sand-catching section was to be provided in combination with a spillway. (From inspection of the steep, precipitous canyon-side I fear these open, unlined canals would not have been practicable for a public water supply. Their line appears to have never been directly surveyed.)

The elevation at the canal intake was planned at about 1955 feet above mean sea level, which is about 725 feet below the level of the floor of the Hetch Hetchy Valley (so this fall would have to be wasted), and the end of the first section of the canal was to be at about 1,800 feet above mean sea level, directly above Bear Gulch, a small tributary of the Tuolumne, about a mile upstream from Moccasin Creek, on which the powerhouse of the present project is planned.

Power Development in Plan of 1902

(158) The power drop by the Grunsky plan at Bear Gulch was 756 feet gross for 125 second-feet or ultimately 250, as against 1,250 net feet obtainable with 620 or 750 second-feet in the beginning at the Moccasin Creek powerhouse. The 60 million gallons per day were to be taken down his power

drop over the hillside in a pair of pipes, each 1950 feet in length, 48 inches in diameter at the top, 30 inches diameter at the bottom. In the powerhouse three impact water-wheels were to be placed with an aggregate capacity of 12,000 horsepower, to which three generators of an aggregate capacity of 6,000 Kilowatts, were to be direct-connected. The electricity was to be stepped up to 40,000 volts and carried a distance of 75 miles to the proposed pumping station on the westerly side of the San Joaquin Valley.

This power generated under the Grunsky plan was to be substantially ALL USED FOR PUMPING the 60 million gallons or any necessary part thereof, over the summit near Altamont. Sixty million gallons daily, under 756 feet, should generate about 6,300 net mechanical horsepower, and 250 second-feet about 16,500 horsepower; but because of the various friction losses it necessarily requires the fall of about 300 feet to lift the same water 100 feet by turbines, electricity and pumps.

It was proposed to take more water into the canal than was required for the city and any surplus of water coming down the canal and not required for delivery into San Francisco was to be returned to the Tuolumne River at the Bear Gulch power station.

The present project develops no power in the immediate future, but conserves the opportunity for developing at its No. 1 power site 70,000 net horsepower available for any purpose, and in its final form the present project gives 157,500 of 24-hour horsepower available for any purpose, where the Grunsky plan gave none.

Continuing with the Grunsky project, the water for San Francisco was to pass from the turbines into a small open reservoir which would collect it again into a pair of 48-inch pipes that would form an inverted siphon across Bear Gulch for the delivery of the water into the lower section of the canal, and would cross Moccasin Creek through a pair of riveted steel siphon pipes, each four-feet diameter and a little more than a mile in length, under 350 feet head at the bridge on which they cross. On rising to the opposite side of this steep Moccasin Valley uptakes of these Moccasin Creek siphon pipes discharge into a second section of the lower canal, which is carried over rocky broken ground requiring three tunnels aggregating about one-half mile in length. Four or five miles farther along the conduit crosses the main Tuolumne River in another inverted siphon, again consisting of a pair of four-foot riveted steel pipes, each about one mile in length, supported at the river crossing on a three span bridge, 500 feet long. At the bridge level these siphon pipes are under a head of 375 feet.

Leaving the Tuolumne the water again flows through a short distance of open canal; then passes into tunnel half a mile in length; crosses another creek in siphon pipes four-fifths of a mile long; thence a tunnel 1,100 feet long; thence again in pipes across a small creek; then again in a tunnel two miles long. These latter tunnels of the Grunsky plan will be thru slaty formations and the estimate covers lining them thruout. These tunnels and the steel pipes on this lower section all have a fall of eight feet to the mile. (In the present project a declivity of 10 feet for actual slope and 8 feet for ordinary hydraulic grade is adopted throughout the Sierra division.) From these tunnels a short canal carries the water to the top of the second power drop at an elevation of about 925 feet above mean sea level.

The present project has no power house here, but uses the head to cross the San Joaquin Valley without pumping the water up over the opposite side of the valley. It goes thru the hills west of the San Joaquin instead of over them.

(159) At the head of this second Grunsky power drop one or two small reservoirs are to serve as equalizers and are to be formed by earthwork dams. Thence a pair of pipes each nearly three-fourths of a mile in length lead to the Dry Creek power station, which has a power drop of 330 feet. Here power was again to be developed from the 60 million gallons daily, by means of three impact water-wheels, aggregating 4,500 horsepower, direct-connected to three generators having a total capacity of 3,000 Kilowatts and feeding into the transmission wires leading from the Bear Gulch power station across the Valley to the pumps.

Leaving the water-wheels, the water enters the pair of 48-inch pipes at an elevation of a little less than 600 feet above sea level and continues in a pair of 4-foot pipes all the way to San Francisco, passing on its way across the San Joaquin Valley thru a pumping station and thru a summit reservoir, as later described.

Crossing the San Joaquin Valley

(160) The pipes from across the valley in the Grunsky plan terminate six miles east of Altamont in a pump supply reservoir of 65 million gallons capacity, formed by an earth dam 920 feet in length, with water surface nearly 200 feet above the mean sea level. The pipe line across the San Joaquin River will be under a pressure of 330 feet near the river crossing. All of Mr. Grunsky's pipe line across the great valley, having a total length of 60.5 miles, will be covered with two or three feet of earth, except the portion on the trestle near the river. The length of the submerged pipe under the San Joaquin is to be about 700 feet.

Plan of 1902---The Altamont Pumps

(161) At the Altamount pumping station, Mr. Grunsky estimates that the sixty million gallons would not generate a sufficient amount of power by passing through the two pump stations at Bear Ridge Gulch and Dry Creek to lift itself up again to the level of the summit at Altamont, therefore, it was planned to make good whatever small deficiency might exist by means of

bringing down the 26 miles of canal from the intake to the Bear Gulch powerhouse, somewhat more water than was required for delivery at San Francisco, and it was noted that this use of the surplus water would in no wise interfere with the right of the irrigation district farther down, because it was returned to the Tuolumne at Bear Ridge Gulch.

The pumping station was to comprise six pumps each of ten million gallons capacity, three of these to be provided with compound condensing steam engines which would be commonly out of service, and used only for emergencies when the electrical power is temporarily interrupted.

The present project contains no pumps in the aqueduct line, and therefore needs no equalizing reservoirs at pump suction or at pump delivery.

At the Altamont reservoir, the pumped water was to be delivered at about 750 feet above the mean sea level, the maximum lift on the pumps, including friction head, being about 625 feet. (This, it will be noted, imposes about 113 feet greater head on the part of the pipe near the pumping station than is imposed on any part of the gravity line in the present project.)

The summit reservoir at Altamont was to be formed by an earth dam 40 feet high across a small valley, and covering about 48 acres and containing when full about 200 million gallons.

Between the Altamont reservoir and the City, nothing requires special note save that a tunnel about a mile in length is required through the ridge near Calaveras Creek and that another tunnel about half a mile in length is considered the best method of passing through the ridge between Calaveras creek and the Santa Clara Valley.

Summary, Project of 1902

(162) Summing up the total lengths of the conduits under these plans of ten years ago, we find a total of 28.6 miles in open canal, mostly following the irregular contour of steep canyon sides; 13 miles of tunnel; 141 miles in distance covered by two 48-inch iron pipe siphons and pressure pipes to power stations, making from intake to city a total length of 182 miles, where the present project has about 27 miles less because of more direct routes, with *the complete elimination of all open canals, open reservoirs in the aqueduct line and the elimination of six miles of wooden trestle support and the steel bridges.*

I have described the project of ten years ago thus in detail both for the purpose of indicating that the Garfield permit of 1908, which was based upon so different a design and for such different purposes, would hardly be expected to fit present conditions and in order to indicate the far greater complication and far greater possibilities of interruption with structures thus planned in order to *reach out to such great distance for so small a quantity of water,* and wherein it was necessary to economize at every point and reduce the aqueduct to the cheapest possible type, an open hillside ditch 28 miles in length, exposed to rainwash, to land slides and rock falls, to pollution from the falling in of field animals, snakes, etc., etc., and with a prospect that the seepage losses would be very large prior to the time when a large additional expenditure, accompanied by serious interruption to the flow was incurred for lining the canal. In the necessity for keeping the cost low, types of structures were adopted that in my judgment were not suitable for the purposes, and the mountain side on which the open canal was to be built is so steep in many places that I question the safety and the cost. I do not understand that Mr. Grunsky's line in the canyons was actually run out on the ground.

A Large Scale Project Required for Success

(163) So long a project must be a large project with broad scope in order to work out well; in other words, in order to make an aqueduct 172 miles long into this difficult region commercially successful it must be of large capacity and planned on a generous scale, and if possible must earn something from its surplus capacity during the years while waiting for the city to grow.

The Manson Variant on the Grunsky Plan

(164) The opportunity to complete the city's title to the Hetch Hetchy site having failed, Mr. Marsden Manson, City Engineer of San Francisco, on July 24, 1908, or as soon as practicable after the date of the Garfield permit, hastily prepared a variant from the Grunsky plan, making only such changes as necessary for utilizing Lake Eleanor first instead of Hetch Hetchy, as required by the terms of the Garfield permit. He retained the feature of open canals of much the same character as the mining ditches of early days, and his estimates assume that the water discharged from Hetch Hetchy would for all time flow down the natural river channel for a distance of about sixteen miles to the site of the diverting dam previously selected by Mr. Grunsky at a point about two miles below the junction of the stream from Eleanor and Cherry Valleys with the main Tuolumne. He proposed a dam at the outlet of Lake Eleanor 150 feet high, which he estimated would cost, including 10 per cent for engineering and contingencies, about $2,000,000, or $814,300 more than Mr. Grunsky had found the cost for the dam at Hetch Hetchy.

Otherwise he adopted all of Mr. Grunsky's design and all of the figures of Mr. Grunsky's estimates of cost made six years before, without change, in the estimate which he presented to the Board of Public Works on September 14, 1908.

(165) Subsequently, in 1910, Mr. Marsden Manson in the effort to design water supply works of 60 million gallons daily capacity from the upper Tuolumne in compliance with

the order to use Lake Eleanor first, prepared another variant from the Grunsky Plans in which he supplemented the water supply of Eleanor Creek by a diversion from Cherry Creek of as much water as could be conveyed by gravity in an open canal of 500 second-feet capacity; and in the effort to secure additional benefits to the city for helping to carry the burden of cost in the Eleanor development, he extended the design so as to provide for the generation of a large amount of electrical power for general municipal purposes by means of utilizing the fall of the water between Lake Eleanor and its junction with the Tuolumne.

Instead of open canals he provided for covering all of the canals below the storage reservoir of Lake Eleanor and those below the point of diversion from the Tuolumne of the water coming from the Hetch Hetchy. With the exception of this elaboration of the electrical power project and the substitution of Eleanor and Cherry for the Hetch Hetchy and the covering of the canals and the short cut across the head of San Francisco Bay the plans were substantially the same as those of 1902.

Mr. Manson's Eleanor-Cherry Project of 1911 Conformable to Garfield Permit

(166) In 1911 Mr. Manson added to his plans and amplified the features of electric power. In supplementary plans prepared by Messrs. Hunt and Van Norden the lines of pipe to the city are shown 50 inches in diameter, but the cost thereby added is compensated for by shortening the line seven miles, more or less, by crossing at Dumbarton instead of going around the head of the bay on the line adopted by Mr. Grunsky; and steel is adopted as the material for the pipes.

(167) Mr. Manson's latest changes from the original plans are as follows:

(1) A diversion overflow dam on Cherry Creek, built of granite masonry in cement, located about five and three-fourths miles upstream from the reservoir site surveyed by Wm. Ham. Hall of which plan from the Cherry reservoir site surveyed by Wm. Ham. Hall (and which it is proposed to utilize in the Freeman project) Mr. Manson carries his intake upstream to this point in order to reach an altitude sufficient for flow by gravity into Lake Eleanor after raising the level of Eleanor.

(2) A canal leading from said Cherry diversion dam into Lake Eleanor, comprising about two and a half miles of open ditch and about two miles of tunnel and having an estimated capacity of 500 second-feet, in order to divert to a maximum of 500 second-feet from the flood flow of Cherry Creek, which at peaks frequently rises to above one thousand second-feet for several weeks at a time, and occasionally reaches a flow of 3000 second-feet. This canal would, therefore, fail to conserve much of the flood flows of Cherry Creek, but any larger diversion canal appeared impracticable because of its great expense.

The above dam and diversion canal were estimated by him to cost about $422,000, but at unit prices so low that I am of the opinion they could not possibly be obtained in that rough and remote country, if cost of road-building, transportation and ordinary overhead costs are included. My judgment from a hasty estimate is that they would be quite as likely to cost double that sum.

(3) A dam of granite masonry at the outlet of Lake Eleanor suitable for raising the level of the lake about 85 feet and for adding 25 billion gallons to its contents. This at minimum prices which I believe could not possibly be obtained when cost of bringing in the cement and ordinary overhead costs are reckoned in, was estimated to cost about $1,150,000. After a hasty review of the items I think it quite as likely to cost more than 50 per cent. additional.

(4) A conduit from Lake Eleanor to the top of a power drop near North Mountain for conveying the combined waters of Eleanor and Cherry, consisting of about two and a half miles of canal, lined and covered with concrete, and about five miles of tunnel, six feet in net diameter, where lined with cement, of which it was expected that the greater portion being thru granite would require no lining. This conduit to be of 125 second-feet capacity, equivalent to about 80 million gallons daily. The cost of this covered canal and tunnel about 7½ miles in length was estimated at about $336,000, but at unit costs so extremely low that I do not believe them possible in this rough and inaccessible region. As a matter of judgment, without detailed estimates, I would expect the required expenditure would be very much more than estimated—possibly double.

(5) A hydro-electric power station located on the main Tuolumne River at the foot of North Mountain, about three and a half miles downstream from the park boundary. This would have a gross head of about 1950 feet.

(6) The plans and estimates for this and the other power stations at Bear Gulch and Dry Creek were prepared by Mr. A. M. Hunt of San Francisco and show a possible development of about forty thousand mechanical horsepower, part of which would be used up in pumping the water over the summit at Altamont.

(7) A diversion dam on the main Tuolumne River just below the boundary line of the National Park and a canal along the canyon side for conveying the water that comes from the natural flow of the Hetch Hetchy without storage for a further generation of power for municipal purposes. The conduit comprising about one and one-quarter miles of unlined tunnel and about two and one-half miles of covered conduit, notched into the canyon side.

This section comprises about three and three-quarter miles and was estimated to cost about $305,000. Considering the circumstances, it is my belief it might cost from 50 to 75 per cent. more.

(8) A main Tuolumne canal from North Mountain power station to the South Fork of the Tuolumne River, capacity intended to carry ultimately 563 second-feet to the South Fork power station, this comprising about four miles of tunnel and three and one-half miles of covered conduit, notched into the canyon side, lined and covered with cement.

The favorable estimate was made that only one-tenth of the length of this tunnel would have to be timbered and only two-tenths lined with concrete. It is estimated to cost about $628,000. My belief is that it would probably cost nearly double that sum, in view of the rough country and difficulties under which the work must be performed.

(9) At the South Fork of the Tuolumne another power house was to be built and from that point the conduit would continue to Bear Gulch power station of the Grunsky plan, and thence to the first Dry Creek power station, but with the difference that it would be lined and covered with cement concrete instead of open. He makes the favorable estimate that only one-tenth of the tunnel might have to be timbered and only four-tenths of the length of the tunnel lined, and by adopting low unit costs derives a figure of $1,425,000. I think it not improbable that a million dollars would have to be added here to cover cost added for the unfavorable surroundings.

From that point to the City of San Francisco there is no substantial departure from the Grunsky plan, and I find no occasion to add any large sums to his estimate, for the conditions effecting construction between the foothills and the city are far less severe.

(168) It should be borne in mind that Mr. Manson's additions provide much larger means of water power than those of

the Grunsky plan, which might be available for various municipal uses and, if fully developed, would leave a surplus beyond any amount that the city could use and beyond what would be needed for pumping the water over the Altamont Pass.

This plan was made, as I understand it, with the object of trying to work out a practical scheme at the lowest possible cost for complying with the order to develop Eleanor and Cherry prior to the Hetch Hetchy, and the further purpose of finding if the city could develop electricity at a profit from this water in its course down the mountains.

The figures are interesting but the plan is not one which I could recommend the city to adopt. As already stated, I am strongly of the opinion, after having studied the situation off and on for more than two years, that the only sound and proper engineering basis for supplying the city with water from the upper Tuolumne is to begin by building the dam at the outlet of the Hetch Hetchy Valley.

It was the intention to file this report of Mr. Manson's with the Board of Army Engineers on August 1st. Mr. Manson has been unfortunately suffering from illness and overwork and this has delayed its final revision. My review presented above has been made from incomplete and unsigned papers, and possibly the estimates of cost that I have quoted, have not had his personal study. Nevertheless it is useful in the present discussion for showing the difficulty of getting anywhere with a small capacity project which starts at Lake Eleanor.

(169) It is to be noted also in considering both the above projects by Mr. Grunsky and Mr. Manson that no large terminal reservoirs sufficient to sustain draft for a long period in case of interruption to the line were provided, and that altho the conduit was subdivided into two pipes for greater safety, as also greater ease in handling, these pipes were everywhere supported on the same bridge and that in crossing the marsh lands near the San Joaquin and in the Santa Clara Valley they were to be carried largely on wooden trestles, the total length of the bridge trestles being about 6½ miles. In other words, the project of 1902 duplicated the pipe line for safety, but had a single canal, single tunnels and single bridges and trestles. The present project also has a single tunnel line and ultimately two pipes across the valley, but although up to a delivery of 240 million gallons daily it trusts to the one pipe, it relies for safety against accident, upon reservoirs holding six months' or a full year's supply, fairly near to the city.

The Garfield Permit is Outgrown, and a Broader Grant is Now Proper

(170) The Garfield Permit, which granted in 1908 to the City of San Francisco certain rights of way thru the National Forests and rights to flood certain lands contiguous to lands owned by the City, was based upon the Grunsky studies chiefly completed ten years ago. During these ten years this water supply problem has broadened so as to include providing for the future of all of the principal communities around San Francisco Bay,—Berkeley, Oakland, Alameda, etc.,—all of which comprise today nearly double the population of San Francisco alone. It is now proposed to join these communities in a Metropolitan Water District like that of Boston, Mass., or perhaps to unite the municipalities into a Greater San Francisco, following the example of New York.

The prospects for prompt and large growth of population thruout the Greater San Francisco have now become far more clearly defined and of much fuller promise than ten years ago, because of the nearing completion of the Panama Canal and the growing appreciation of what this will do for San Francisco, because of the increased prospects of the extension of commerce from San Francisco to the Orient, and because of a great awakening in intensive farming in the Great Valley.

Moreover, within the years since making the Grunsky studies, which formed the basis for the Garfield Permit, there have been worked out the problems of the 220-mile aqueduct for bringing 420 second feet of water from the Sierras to the City of Los Angeles. This Los Angeles project has suggested a new plan of developing the Tuolumne waters for San Francisco, and plans have been worked out for making the surplus flow of Owen's River water, secured now in anticipation of the continued growth of Los Angeles, and which can be conveyed in the surplus capacity of the aqueduct, useful for irrigation until the time when it is needed for domestic supply; thereby helping to provide income for paying interest upon an aqueduct of the large capacity needed in future for the domestic supply, in which the tunnels and masonry must necessarily be built full size at the start.

Similarly, the Tuolumne water can be made to generate far more power than under the plans of ten years ago, and a large volume of water now wasted in floods can be made to aid intensive farming and kitchen gardening on some thousands of acres around San Francisco Bay, tending to cheapen the city's food supply.

Also in the years since the Garfield Permit, the natural limitations of the land areas that can be irrigated in the Modesto and Turlock district are now better understood, and the facts regarding the water-logging of the soil from over-irrigation in parts of these districts, have become far more clearly developed.

Meanwhile, also, negotiations for the purchase of the Spring Valley works by the City of San Francisco have made much progress; in fact, they lacked but few votes of becoming consummated eighteen months ago.

In the above matters and in many others, the scope of the

Hetch Hetchy water supply problem and the scope of methods for solving it have become greatly changed and the scope of the Garfield Permit it insufficient for present needs and for future conservation.

(171) Regarding the Hetch Hetchy Valley as a pleasure ground, criticism of the city's earlier plans has resulted in bringing much new light to bear on this problem. It is becoming plain from business reasons and because of the stronger appeal of other worthy objects for public funds, that instead of being opened up and made available to the many, this valley will remain thruout the life of the present generation a sort of private camping preserve for the very few who either have the leisure for a very slow tour or who can spend money freely for guides, horses and packers. It can be opened to Californians and to others in co-operation with the city, by the road-building, which must precede works for water supply.

The Present Water Supply Needs

(172) The city of San Francisco and substantially all of its neighboring municipalities are today either suffering from an insufficient water supply or have no sufficient reserves for future growth, as shown by statements in the appendix.

In San Francisco this insufficiency has been manifested chiefly by failure to extend the pipes so as to provide for growth or so as to encourage the spreading of the population into the outlying districts of the city. In addition to this delay in extending pipes and notwithstanding that the corporation supplying San Francisco owns undeveloped water rights which it claims are of large capacity, the city is today under the shadow of a scant supply from the present pipes, should there come two seasons in succession with as low rainfall as has sometimes occurred.

Why Build the Hetch Hetchy Aqueduct So Large?

(173) The question will be raised in the San Francisco metropolitan district as it was in Los Angeles "why build works at present of capacity so much larger than the immediate need"? At Los Angeles it was most vigorously urged that a steel pipe perhaps thirty or forty inches in diameter and sufficient to convey, say twenty-five to forty million gallons per day, would supply all of the probable need as far into the future as one could safely estimate the increase in population and the demand for water and that a pipe of this reasonable size would tax the city's resources far less than the large tunnels and concrete aqueducts.

It was, however, strongly suspected that these arguments were put forward chiefly in the interests of the corporations having electric power to sell and which feared the competition of the fifty thousand or seventy-five thousand electric horsepower that it would be possible for the city to develop progressively as called for, along the course of the full-size aqueduct.

(174) The two chief reasons for building the Los Angeles Aqueduct of full size in the beginning, apply also in the case of San Francisco metropolitan district.

The first reason is that in a region where the value of water is increasing so rapidly with progress in vastly broader areas of irrigation, it is important to make the water rights secure by actual diversion of the full appropriation and place them beyond all possibility of future adverse claims, by immediate application to beneficial use.

The second reason why San Francisco must build so large an aqueduct, is that in a rough mountainous country and where the water must be conveyed in covered conduits to protect it from pollution, it is only a large quantity that can be economically conveyed by tunnels thru solid rock (or where supporting ground can be found at the right elevation, conveyed in so-called cut and cover aqueducts built of concrete masonry), and it is necessary to build such tunnels and aqueducts of full size at the start.

Scale of New Works

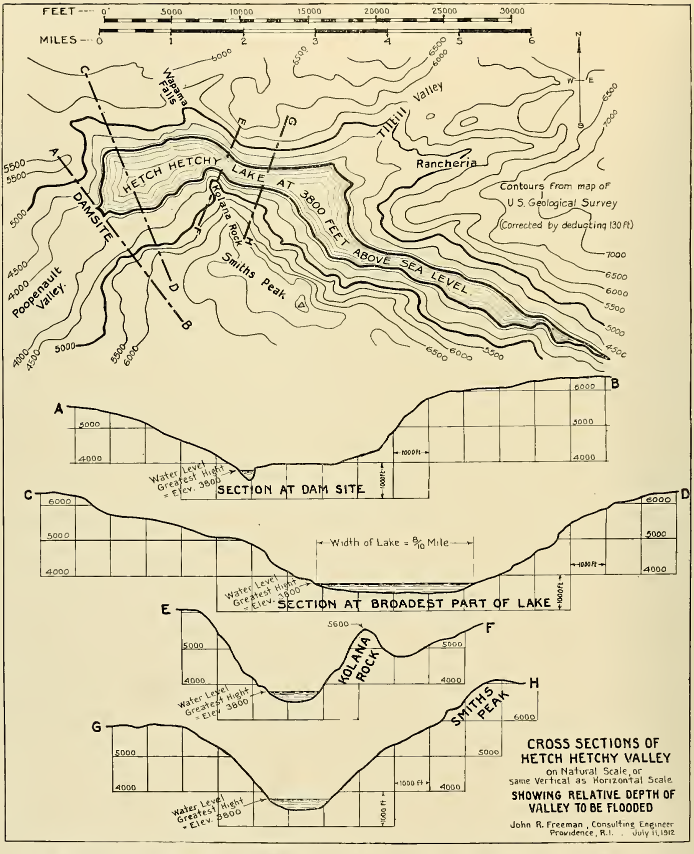
(175) It is a matter of elementary engineering that the cost of conveying a given quantity is far less in one large aqueduct than two or three small aqueducts, and prior to discussing this fact mathematically it is of interest to note what certain other large cities have built.

Boston fifteen years ago designed its great Wachusett aqueduct of 300 million gallons daily capacity, altho the whole Nashua River flow, most fully conserved, could amount to only 118 million gallons per day, because this aqueduct was planned to also bring in the distant future water taken from more remote rivers.

New York City today is building its Catskill aqueduct from the Esophus watershed of 600 million gallons estimated daily capacity, altho when most fully conserved this watershed can yield but 250 million gallons, because at some future day the Scoharie and Roundout (and perhaps the Catskill Creek) watersheds will also be made tributary.

Los Angeles is building its aqueduct of 420 second feet, which equals 273 million gallons daily capacity, where the city's utmost need in domestic water supply from this new source for twenty years to come can hardly amount to a fifth part of this quantity.

One reason in each of the above cases is that tunnels and masonry aqueducts form a large part of the aqueduct line, and that a WATER SUPPLY TUNNEL OR A MASONRY AQUEDUCT CANNOT BE ENLARGED BUT MUST BE MADE FULL SIZE AT THE START.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MILES 0 1 2 3 4 5 6
N
W E
S
Wapama Falls
Tiltill Valley
Rancheria
HETCH HETCHY LAKE AT 3800 FEET ABOVE SEA LEVEL
DAMSITE
Kolana Rock
Smiths Peak
Poopenault Valley
Contours from map of U.S. Geological Survey
(Corrected by deducting 130 ft)
4000
4500
5000
5500
6000
6500
7000
A
B
C
D
E
F
G
H
Water Level Greatest Hight = Elev. 3800
SECTION AT DAM SITE
1000 ft
SECTION AT BROADEST PART OF LAKE
Width of Lake = 8/10 Mile
5600
KOLANA ROCK
SMITHS PEAK
CROSS SECTIONS OF HETCH HETCHY VALLEY
on Natural Scale, or same Vertical as Horizontal Scale
SHOWING RELATIVE DEPTH OF VALLEY TO BE FLOODED
John R. Freeman, Consulting Engineer
Providence, R.I. July 11, 1912

Sections illustrating the small depth of submergence proposed in comparison with depth of valley and height of cliffs (all sections on natural scale.)

A second reason is, that it is plainly the part of wisdom to safeguard the quantity of water available for the future supply of any great and growing commercial city. For this second reason Seattle, like Los Angeles, has reached out and acquired control of a large watershed in the Cascade Mountains, which will yield a supply of pure mountain water many fold greater than its present needs and the National Government has generously helped it to do so.

Portland, Oregon, has discarded its former supply, taken from the great river that flows past it, and has gone thirty miles back into a rough, uninhabited mountain region and established a forest preserve of 222 square miles area for the continued protection of its source, and from this has built two large pipe lines into the city.

San Francisco in seeking a future mountain source for softer and more palatable water is following the examples of its rivals in the commerce of the Pacific,—Los Angeles, Seattle and Portland.

Alternatives for Duplicating Aqueducts

(176) Danger in reliance upon a single great aqueduct in the case of San Francisco fortunately can be safeguarded by means of great storage reservoirs near the city.

In a similar way the City of Boston trusts for the future mainly to its great Wachusett aqueduct with its great distributing reservoir at Spot Pond; similarly New York is building its great Kensico reservoir near to the city, to safeguard the posibility of accident to its one great conduit from the Catskill Mountains; and San Francisco in its present Spring Valley reservoirs and the other Bay cities in their present supply works have even more generous safeguards for permitting one great aqueduct to be built in the cheapest form. The uses for local kitchen gardening and possibly those for electric power can hasten the date when other reservoir dams and other portions of the steel pipe lines can profitably be built.

Only a Public Water Supply Can Afford to Properly Develop Hetch Hetchy

(177) No corporation, no irrigation district or no single municipality other than San Francisco could possibly afford to build works sufficiently extensive to fully conserve the water on the upper Tuolumne now wasted in floods, because of the vast expense involved in these works under the local conditions.

There is a clearly defined limit of rental cost or water assessment per acre foot delivered beyond which agriculture, particularly such as practiced in the Modesto and Turlock districts, cannot afford to pay, and there are well defined limits beyond which the storage of water for power cannot be made profitable in competition with power generated by steam or gas engines from petroleum or coal; but a generous water supply is so vital to the life, health and comfort of any community and, however expensive, is so cheap per individual per year, in proportion to his other living expenses, that almost any cost that may be necessary for dams or conduits, can be made. But at the same time the municipality that would best minister to the health, comfort and the higher pleasures in the daily life of its citizens always finds more opportunities for expenditure than it has funds or borrowing capacity to meet, and so each dollar unnecessarily expended on water supply tends to lessen the expenditure available for the best housing of its people or for improving their surroundings and of the younger generation by special schools, by parks and by a dozen lines of wise paternal activities.

Economy

(178) It will be demonstrated by the reports on alternative sources now nearing completion that after the limits of the various present sources have been reached in the near future that by far the best, cheapest and most satisfactory source of water supply, can be had from the Tuolumne River, with storage in the Hetch Hetchy Valley. This fact was proved by Mr. Grunsky ten years ago and again proved in the various reports by Mr. Manson, and now it is proved with more elaboration of detail.

Conservation of the financial resources of these cities about San Francisco Bay must be given due weight in this matter, no less than the conservation of the flood waters which now run to waste, and no less than conservation of opportunity for recreation in the Sierras. If Greater San Francisco can save ten million or twenty million dollars by developing the Tuolumne source at Hetch Hetchy, as appeared to be the fact from the rough estimates based on data of Mr. Grunsky's 1902 report and from the more elaborate recent investigations, as compared with the next best possibility for meeting the water supply needs of 25 or 50 years hence, the sum thus saved can be applied to other public uses—to parks, pleasure roads, municipal auditoriums (like Denver's, for example, with free public concerts), and to a broader extension of the work of municipal embellishment already begun, and this fact must be given much weight, notwithstanding it may be physically possible to obtain large quantities of water at some higher price from various other sources.

The superior quality of the Hetch Hetchy water, its remarkable softness and the better relish with which a million people can drink water from such a source are elements to be reckoned upon in comparing values.

Adding to the Enjoyment of the Yosemite Region

(179) By the use of the bottom of the Hetch Hetchy Valley as a reservoir site for storing flood waters for the use of the

San Francisco Metropolitan Water District, the enjoyment of the natural beauties of this valley can be a hundred-fold increased. If a beautiful region can be brought within the vision of a hundred appreciative nature lovers instead of closed by time, hardship and expense of the trip to all but one or two, the enjoyment of this beauty has been fifty or a hundred-fold increased, and it is so simple as to require no argument that the two beautiful cliffs in the Hetch Hetchy Valley would become more beautiful when mirrored in a deep, placid lake more than half a mile in width and several miles long.

Nine out of ten of the future visitors to Hetch Hetchy, whenever it is made accessible, will probably be citizens of the San Francisco District or its guests, and the municipality is therefore justified in adding to the expense of its water supply the cost of building a scenic road around this future lake and in building a highway of best workmanship into the region and maintaining it open as a pleasure drive for all time; just as the corporations of Manchester, Liverpool and Birmingham have built beautiful macadam pleasure roads around their distant water-supply reservoirs of Lake Thirlmere in the English lake district and around Lake Vyrnwy and Craig Gôch in Wales. The long road into the region on an easy grade, will be a necessity for transportation of supplies to the dam and aqueduct builders and its continued maintenance will be a safeguard for prompt repairs.

The Present Inaccessibility of Hetch Hetchy and the Few Who Enjoy It

(180) Notwithstanding the Hetch Hetchy Valley has for some years past been one of the best advertised pleasure spots in the United States, by reason of appeals published by the Sierra Club and by various gifted writers, and notwithstanding the fact that during the month of September, after the mosquito pest is over, this valley is veritably a "paradise for campers," very few campers go there for pleasure and the number from outside the State of California is particularly small.

The few soldiers who act as guardians of this part of the National Park keep a record of every visitor, whether tourist, cattleman or surveyor. In the year 1909, the Sierra Club widely advertised an excursion into the Hetch Hetchy, but even in that year and including the Sierra Club, which has a membership widely scattered thru the United States, the total number of visitors from June to September inclusive, included only seventeen persons from outside the State of California, and among these seventeen were only four whose homes were East from Chicago.

The total number of visitors listed during the season of 1909, including the forest rangers, the surveyors employed by the City of San Francisco, the cattlemen from adjoining counties, and counting over and over again in the number of visitors the repeated visits of the city's surveyors and packers bringing in food supplies to the surveyors, aggregated only 269 persons for the year.

In the year 1908 the official lists of visitors to the valley on file with the Department of the Interior shows the first entry about the first of June and the last entry on September 30th, and the records for the entire season show that only two persons from outside California visited the valley, both of these from Kansas.

In the year 1910, the list begins on May 27th and ends October 3rd, and includes only sixteen persons from outside California, five of whom were from New York, one party of four from Philadelphia, one from Boston, and one, myself, from Providence.

In the year 1911, the season opened late, owing to heavy snows and swollen streams. The Army Board of Advisory Engineers and the City Engineer's party, of which I was one, were among the earliest visitors and found mosquitoes too plentiful in the meadows to encourage early arrival. The first entry is July 10th, and the 1911 list shows many more visitors from outside the state than before, mainly because of a largely attended excursion of the Sierra Club on July 30th, which came in 185 strong, of whom 37 were from outside California and 148 were Californians, 20 from San Francisco.

(181) Year by year the records show that by far the greater number of the visitors listed either came from the cities about San Francisco Bay or from the neighboring agricultural districts near the foot of the mountains. The reason for this small number of visitors from outside the State becomes plain to one after he has made the trip and found out about the inaccessibility, the hardship to one not accustomed to the saddle, and the expense; and if one has happened to time his camping on the valley floor during the mosquito season he cannot truthfully describe that part of the trip as a pleasure excursion.

A pair of campers can hardly make the trip if bent on pleasure, in less than a week's time nor can they readily do it for a smaller expense than $200 for that portion of the journey beyond the nearest stage line. My information on this is from Mr. Bartlett of Hamilton, who lives near the end of the good wagon road and supplies most of the visitors with saddle horses.

What one finds there today is beautiful, but it is relatively tame and uninteresting in comparison with the far more grand and varied Yosemite.

Adding to Hetch Hetchy's Attractions

(182) The flooding of the valley floor, giving in its place a deeply sheltered lake with an outlet so planned that the bottom could never again become uncovered, would present features

different from anything found in the Yosemite or elsewhere in California. The flooding of the margins and the stocking of the lake with trout would cure the mosquito pest and would thus double or perhaps treble the length of season in which one can visit the valley with pleasure. There would be no mud left on the fore shore by the receding waters, the river here commonly runs clear, and since the shores will mostly be bare ledge, the change of level must certainly present even less objectionable features than the uncovering of the margins of the great reservoirs of Boston, New York, Baltimore, Newark, etc., etc.

Altho some of the most beautiful camp sites would be flooded, dozens of other beautiful camp sites would remain.

Benefits of New Roads

(183) The building of the road necessary for the city's works would open the region to hundreds who could never enjoy it otherwise and considering the proportion of the visitors shown by the records to come from Greater San Francisco, the cities about the bay might well maintain this road as a permanent easy-grade road for pedestrians, carriages or automobiles, and the State might well co-operate in making the portion of the road between, say, Groveland and the nearest railroad point, a State road, and the Federal Government could well co-operate by improving the portion between the Yosemite, and say, Colfax Gate, so that the trip to the Hetch Hetchy Lake and its surroundings could form a part of the Yosemite tour. The city's road from near Groveland into Hetch Hetchy is being planned with the remarkably easy grade of 3 per cent, and curves nowhere less than 30°, or 193 feet radius.

(184) The city might further, at relatively small expense, develop the right of way for its steel pipe line across the San Joaquin Valley into a broad highway of extra width, beside the pipe lines, and set out double rows of shade trees on either side, perhaps leaving the roadbed for the State to maintain. This would add to the pleasure routes for the citizens of Central California and would provide a much better highway between the fertile agricultural districts of Modesto and Oakdale and the metropolis than any which now exists and also tend to better development of a broad strip of country on either side.

The Garfield Permit

(185) This permit was in the form of a communication by the Secretary of the Interior, addressed to the Commissioner of the General Land Office, dated May 11th, 1908, and concluded with an approval of the maps of location for the Lake Eleanor and Hetch Hetchy reservoir sites as filed by James D. Phelan and assigned to the City of San Francisco, SUBJECT TO FILING BY THE CITY OF A CERTAIN STIPULATION and the fulfillment of the conditions contained therein.

These stipulations on behalf of the city appear to have been filed under misapprehension of the actual conditions. There was then no such understanding of the conditions as has since become apparent, and there was at that time no conception of such a plan as has since been worked out.

The Garfield Permit contains various provisions which are now found to be contrary to the public interest, as for example, the following:

Under Stipulation 3, San Francisco covenants to develop the Lake Eleanor site to its full capacity before beginning the development of the Hetch Hetchy site, and to begin the development of the latter only when the needs of the city and adjacent cities require this.

To do this would be, under light of the present day, an economic blunder of the worst kind, wasteful of the city's funds and in gross violation of the principles of conservation of water supply. Seldom, if ever, has an economic fact been more plain than that it is logical, economical and in all ways proper to build the Hetch Hetchy dam first and to defer building any high masonry dam upon the unfavorable, expensive Lake Eleanor site for fully half a century.

In Stipulation 4, the city practically agrees without investigation, to a validation of certain water claims as filed, without regard to the actual proper legal measure or to the question of beneficial use, and while the city has no disposition to interfere in the slightest particular with any right which these irrigation districts may possess, or to the fullest proper use of their priorities, it now appears plain that a question as to what these rights really are, if the question ever need be raised, should be left to the proper authority, the Courts of California.

In Stipulation 5, the City and County of San Francisco agreed to in no way interfere with the storage of flood waters in other sites than Hetch Hetchy and Eleanor, thereby apparently denying to itself the right common to any citizen to file on any unappropriated waters and to put them to beneficial use.

In item 6, the City agreed, on request, to sell to the Modesto and Turlock Irrigation Districts for the use of any landowner for pumping sub-surface water, for drainage or irrigation, any excess of electric power which may be generated, such as may not be used FOR THE WATER SUPPLY PROVIDED FOR, and for the actual municipal purposes of the City and County of San Francisco, which purposes should not include sale to private persons or corporations, at such price as will actually reimburse the city only FOR DEVELOPING AND TRANSMITTING the surplus energy thus sold, etc.

The city at present does not propose to undertake any power development, but the time may come when these power rights may be a profitable source of revenue, and in view of the burden that the city must undertake in building the proposed dam and aqueducts, it is manifestly unjust to deprive it of any proper source of lightening this burden.

In Stipulation 8, the city agrees whenever it begins the development of the Hetch Hetchy site, to vigorously complete a dam at least 150 feet high and to release, for the benefit of the irrigation districts at Modesto and Turlock, any surplus water that this dam might contain not required for the use of the city AT A PRICE NOT TO EXCEED THE PROPORTIONATE COST CHARGEABLE TO THE VOLUMES THUS LIBERATED.

This would compel the city to store water and deliver it to the Modesto and Turlock districts in the reservoir which it had built at great expense, in preference to delivering it to landowners and truck farmers within or near its own borders, and since the permit names the only customer to whom the city could rent irrigation water, it is not probable the city would get much of a return.

(186) The outlook and the state of the art have moved so fast that the Garfield Permit has become practically worthless for the needs of the city, and a new permit should be drawn in accordance with the scope of the works proposed in the opening paragraphs of this report.

COMPARISONS OF THE UPPER TUOLUMNE RIVER WITH OTHER POSSIBLE SOURCES

Misunderstandings

The misunderstandings and opposition which led to the terms of the Garfield Permit prompt some further statements as to why the Hetch Hetchy Valley should be made available for the public water supply of San Francisco and its neighboring cities.

From the studies reported on the preceding pages and in the various appendices, it can be proved that by taking any source for its future water supply other than those found above the Hetch Hetchy, Eleanor, Cherry and Poopenaut reservoir sites, the San Francisco District would waste certainly more than ten million dollars; ultimately perhaps more than thirty million dollars, because of the greater cost of obtaining from the next best source, the additional amount of water that will surely be required long before the close of the present century; and it is a matter of plain common sense that an extra burden of ten or twenty or thirty million dollars should not be placed on the tax payers and other citizens of the cities around San Francisco Bay merely to satisfy the peculiar views of a few solitude lovers or in order to meet the unreasonable demands of some sentimentalists who have been led astray by misstatements of the case and who have had no direct knowledge of the facts.

No Source is Superior in Quality to the Hetch Hetchy

Plainly, it is an absolute impossibility to obtain a softer, better or more pure water supply than from the Upper Tuolumne and plainly it is impracticable to secure a cleaner reservoir site, or one that will possess a larger proportion of bare granite walls all the way between the high water and low water limits.

Nor is there known to exist within reach on any of the other California rivers a damsite which gives so large a volume of storage for an equal quantity of masonry, as the Hetch Hetchy.

The location of these reservoirs within a national park tends to better sanitary control for all future time and the fact that their catchment lies almost wholly within national forest reserves also tends to remove the possibility of a pollution that might follow private ownership of the lands, and their location within the granite belt of the high Sierras prevents all possibility of pollution from future mine wastes or smelting works.

The granite bed rock of this particular region appears to have been scraped more clean by glacial action than in localities farther north in the Sierras. There is less covering of earth or decomposed rock and never have I seen so clean a gathering ground for domestic water supply as that, for example, around Vernon Lake.

To an engineer familiar with water supply problems, this Hetch Hetchy site is simply ideal, and indeed its value for this purpose is so obvious that when the then principal California hydrographer of the U. S. Geological Survey, Mr. J. B. Lippincott (now Assistant Chief Engineer of the Los Angeles Aqueduct), first explored its water resources a dozen years ago, he perceived its special value to San Francisco and urged the City Engineer (then Mr. C. E. Grunsky) to take steps to secure it.

There is a remarkable absence of good large reservoir sites elsewhere on the Stanislaus, the Mokelumne, the American and Cosumnes rivers, as can be seen unmistakably by studying the maps of the U. S. Geological Survey.

The Real Value of the Hetch Hetchy

The Hetch Hetchy Valley has no conceivable important value except for the two purposes:

(1) Scenery;

(2) Water supply.

By care in the designs, the use for water supply can be made to add greatly to the scenic value, and the large expenditure which ordinary water rates permit upon development work, can bring the scenic beauties of the Hetch Hetchy Valley within reach of a hundred-fold more people than would otherwise find it possible to enjoy them during the next quarter or half century.

Without the use for municipal water supply to carry the heavy burden of cost of building a good road into this difficult region (a million dollars of the estimated cost of the Hetch Hetchy supply will go for road building), it can be plainly seen from the demands of populous regions now poorly served and properly having the first call upon the public funds for good roads, that the Hetch Hetchy Valley will in all probability continue during the next half century under just about the same difficulty of access and in just about the same condition of neglect as we find it today.

Present Neglect and Why

Notwithstanding all of the advertising this valley has had generously bestowed upon it during the past five years in the magazines, newspapers, pamphlets and circulars by literary artists and solitude lovers, and thru skilfully drawn confidential appeals for every nature lover to write a letter of protest to his Congressman, and a campaign presumably financed in part at least by those who have a source of their own to sell, the total number of tourists from outside the State of California who have visited the Hetch Hetchy Valley during the season of 1912 to August 15th, comprises only two tourists (from Missouri), and these came in as guests of a party from San Francisco. The survey party of the City of San Francisco together with the city officials, army officers and soldiers gathered in the valley on August 15th to examine the proposed heights of flowage and verify the city's boundary lines, was probably the largest number of white men ever assembled in this valley at one time, save on certain much advertised excursions of the Sierra Club.

One reason why so few visitors come is that until late in the season the valley now is infested with mosquitoes which breed in the pools left by the receding June floods, so that commonly no comfort can be found here until near the time of year when school and college open and the California vacation season is mostly over, but with the meadows permanently flooded the mosquito pest would be at an end. Another reason is the absence of any wagon road and the roughness of the trail. Still another reason is that except for greater solitude it is inferior to the Yosemite Valley, while of the same order. Convert this valley floor and the valley just downstream into permanent mountain lakes in which the cliffs are mirrored, and this valley will then have a charm of its own.

Wasting a Great Gift of Nature

To prevent the use of the Hetch Hetchy Valley for water storage purposes will waste one of the great natural resources of the State of California. By no other means can a large part of the flood waters which now at times cause harm and add to the dangers of bursting the dikes of the wonderfully fertile, reclaimed tule lands along the lower San Joaquin River, be made useful, for nowhere else is there opportunity within financial reach for building so large impounding reservoirs to restrain these flood waters and make them useful instead of dangerous.

The City's Property Rights and the Public Good

In all of this discussion it must be remembered that the City of San Francisco now owns in fee simple, by far the larger part of the areas in the Hetch Hetchy, Eleanor and Cherry Valleys which it desires to flood for reservoir purposes. So little has the extent of the city's ownership been realized in the absence of plainly marked boundaries that the federal soldiers who care for this park have for years established their camp on lands which the city owns and the telephone poles of their patrol lines are planted on the city's ground and their horses are pastured upon it, and it is land owned by the City of San Francisco that the Sierra Club has camped upon in the campaign of opposition officered by a few of its members.

For the Federal Government to deny to the city the opportunity to purchase or exchange other land which the city owns within the national forest for the small additional area of Federal land required for damsite, rights of way and additional marginal flowage, would be at variance with precedent and would injure some hundreds of thousands of good citizens of the United States, by increasing their water rates and taxes for the benefit of a dozen or so of solitude lovers, or would aid the would-be vendors of some half dozen other less desirable water sources, and in effect such action by the Federal Government would simply smother and destroy the value of the city's property rights in these lands.

For every acre of ground that the city desires to obtain from the United States it offers in exchange land intrinsically just as good or better, for these exchange lands are patented lands and naturally the early settlers picked the choicest spots. The roads which the city will build into the valley at a cost of about a million dollars will always remain of great value to the Federal Government and to the citizens of the whole country and the proposed scenic road and the first-class easy grade wagon road into the valley with continuation to Eleanor and Cherry on which the city is ready and willing to expend about a million dollars are plainly of great public benefit and would open up views now available only to a skilled mountain climber, and in addition be of great benefit to the Federal Government in giving better access to the public lands and for its forest ranger and fire guard service. Because of being built first as a railroad roadbed it will have the remarkably low gradient of 3 per cent, and curves not less than 193 feet radius.

Comparison of Sources for Future City Water Supply

Some of the above statements are so strong that to one unfamiliar with the situation they may appear prejudiced, but all are open to proof and in the following pages it will be attempted to discuss the merits of the respective schemes for bringing an equivalent water supply to San Francisco, in a manner free from all prejudice and without abstruse technicalities.

The starting point in estimating the requirements of a future source for a rapidly growing city is the quantity of water required. During the ten years between the census of 1900 and that of 1910 no large city east of the Rocky Mountains increased its population by so large a percentage as Greater San Francisco, notwithstanding its ordeal of earthquake and fire. Forty-seven per cent increase in 10 years was its record and the recent school census indicates five per cent in each of the two years since the Federal census and there is a certainty of still more rapid growth to come with the opening of the Panama Canal, subdividing of the old wheat-fields into irrigated farms and expanding trade with the Orient.

VALUE OF SOFTNESS OF WATER IN COST OF SOAP

In the preceding pages it has been demonstrated that San Francisco, because of its salt water surroundings, the demands for irrigation in a semi-arid climate and the increase in intensive farming, must look farther into the future when planning its water supply for all time than most American cities, and on pages 77 to 80 preceding, it has been demonstrated from very conservative estimates of future growth in population and increased consumption, that *more than* 400 million gallons daily of additional water supply will be needed by the cities around San Francisco Bay before the end of the present century, possibly within fifty years.

Plainly, it is better to plan a single line of progressive development, as Boston, New York, Los Angeles, Seattle, and many other cities have done, than to seek smaller scattered supplies—a new one every 20 years—for there are disadvantages of extra cost in the management of scattered sources, which promise to far overshadow any possible advantage in a diversity which might lessen the chance of interruption to the supply. A far better line of such progressive development is possible from the Tuolumne than from any other river or combination of rivers.

It has been shown on pages 65 and 67 that with the great storage found in Crystal Springs reservoir with flow line raised to an elevation of 305 feet above mean sea level and with Lake Chabot raised to elevation 350, there will be a sufficient reserve to reasonably meet all risks of accident to the outlying aqueduct, and therefore it becomes plain that a single line of pipe with its lower cost of maintenance and much smaller first cost will satisfy the conditions. The search for a future additional source may therefore be directed to a single source or a combination of neighboring sources that can be brought into the city in a single main line of new aqueduct.

It has been demonstrated (see Appendix 17) that from 400 to 500 million gallons daily can be obtained from these four reservoirs on the upper Tuolumne without injury to the present or prospective irrigation or injury to the navigation and that this water can be made to flow by action of gravity without pumping, into either the enlarged storage reservoirs at Crystal Springs and Lake Chabot, even after these have had their dams raised to the maximum height; or that by slightly thickening the steel pipes to withstand a somewhat greater pressure this water would flow by gravity to the proposed San Miguel reservoir near the center of San Francisco at 400 feet above sea level.

What other possible source presents superior or equal advantages to the Upper Tuolumne?

Advantages of Gravity Flow and Softness

The cost of pumping each 100 million gallons daily of a future supply with the most economical plant up a lift of 280 feet in vertical height would be nearly $300,000 per year, which, capitalized at 6 per cent to include ultimate wearing out and renewal of plant, amounts to $5,000,000, and for the future supply of 400 million gallons daily presents a handicap of $20,000,000 against a source like the McCloud, Feather, or filtered Sacramento water, which has to be pumped.

In its remarkable softness, the Hetch Hetchy water presents an advantage that can be reckoned in dollars and cents in saving in soap, to say nothing of its greater value for the human system or for non-formation of scale in steam boilers.

Whipple, one of the foremost authorities in the world on quality of domestic water supply, shows by careful estimate (see pages 26-28, Whipple on "The Value of Pure Water", Wiley, N. Y., 1907), that for water with increased total hardness of 80 parts per million (as calcium carbonate) and with the assumption that soap is applied to an average of only one gallon per capita per day, the capitalized cost amounts to about $8.00 per million gallons of the total supply. Multiplying this by the present 37 million gallons used daily in San Francisco by 365 days per year we find a handicap of about $108,000 per year against the present source. This figure would not apply to a comparison of the Tuolumne against the Stanislaus, Mokelumne, American and other river waters, which also are soft, tho probably not quite so soft as the Upper Tuolumne.

Whipple found by many experiments that one pound of average commercial soap would *completely* soften 167 gallons of water with a total hardness of 20 parts per million, like the stored Hetch Hetchy water, but would *completely* soften only 45 gallons of water with an average hardness of 100, which Hazen finds for the probable average of the present Spring Valley supply, or would *completely* soften 76 gallons of water with a total hardness of 55 parts per million, like that of the Sacramento at Rio Vista, the best point of diversion for a filtered supply.

This difference on a future total supply of 400 million gallons daily, with a hardness of 55 versus a hardness of 20, is 35 x 0.10 x 365 x 400= $511,000 per year for the whole metropolitan water district, which is 5% interest on ten million dollars, which is a proper handicap against the Sacramento River source in the ultimate development.

Differences in methods of determining hardness require caution in application of Whipple's results to ordinary statistical data on hardness, etc.

Also, see pages 62 *et seq.* of Whipple's book, above quoted, for disadvantages of hardness in a water for industrial uses.

The Hetch Hetchy water is unexcelled in softness, for its catchment and point of diversion are all within the granite of the Upper Sierras, where vegetation and soil cover are scant, and hardness of water is supposed to be caused by the solvent action that water containing carbonic acid has on soils containing lime. The ingredients of swamp water and lime are here conspicuously absent.

Why Use of Hetch Hetchy Should Precede Eleanor or Cherry

Before attempting to answer the question of the preceding paragraph we may pause a moment to discuss the conditions of the Garfield Permit, which recognized the merits of the Upper Tuolumne but required leaving Hetch Hetchy until Lake Eleanor and Cherry had been developed to their fullest capacity.

The chief reasons why the Hetch Hetchy should be developed first are:

(1) That this site will yield twice as much water as the two others combined, from a better basin, for about the same expenditure on construction;

(2) The proposed water supply development will at the same time make the scenery of this valley accessible to the public and greatly diversify and improve it.

There is no good reason why the city should spend the $200,000 which will be approximately the cost of a good broad wagon road about 13 miles long from the Early Intake into the Hetch Hetchy Valley, which happens to cover over the most expensive miles for the entire route easterly from Groveland, unless this road is to be soon used for the delivery of cement and building materials and other supplies to the Hetch Hetchy Dam and the adjacent tunnel portals, and of course it would not build the scenic road and the wagon road from Hetch Hetchy across the divide to Eleanor.

Suppose the order of construction were to be as specified in the Garfield Permit and that because of the enormous expense involved in high masonry dams on the unfavorable Eleanor and Cherry sites (see page 8) aggravated by the steep, long haul of cement to reach them, that earth dams about 90 feet high, each giving 50 feet maximum available depth of water were to be built. The first work would be to build a wagon road about 10 miles long on a canyon-side grade averaging 5 per cent (in places 6 per cent) to overcome the 2,500 feet of vertical rise from Cherry mouth to Lake Eleanor.

The aqueduct from the Cherry Dam to Early Intake would be about 10 miles in length, passing Eleanor at a level about 200 feet below its outlet (wasting this 200 feet of fall for the Eleanor discharge) and comprise probably 6½ miles of tunnel. Proceeding southerly, it would follow the contour of the hill to the top of North Mountain, opposite the Early Intake, from which a thin steel pipe carrying the water at high velocity, provided with air inlets to prevent collapse if suddenly emptied and having a gate at only its upper end, would descend the slope to the Early intake; or if power development was to follow, use might be made of two thicker pipes.

From the Early Intake to the city, the aqueduct for Cherry and Eleanor water would in all respects be as proposed in the present plans, save that pipes of much smaller capacity would be laid across the San Joaquin Valley and across the head of San Francisco Bay, to be paralleled some years later by other pipes; for the quantity of water from Eleanor and Cherry would soon be outgrown when distributed among all of the communities around the Bay that are clamoring for more water.

These Eleanor and Cherry earth dams with 50 feet available water depth would together store about 24 billion gallons and the yield from the two watersheds in critical years like 1897 and 1898, after providing for the irrigation priorities at Turlock and Modesto, would be at most about 80 million gallons daily.

On the other hand, the one Hetch Hetchy Dam, built to the partial height more recently proposed, shown in a drawing near the end of Appendix 9, and with its flow line at elevation 3670, would store about 50 billion gallons and yield about 150 million gallons daily. The extra cost of the long aqueduct line from Eleanor and Cherry to the Early Intake, which would contain about 6½ miles of tunnel between Cherry outlet and North Mountain, plus 3 or 4 miles of cut and cover aqueduct, and nearly a mile of steel pipe over very rough, steep ground, would largely, if not wholly, absorb the difference between the cost of the two low earth dams at Eleanor and Cherry and that of the proposed low masonry dam at Hetch Hetchy.

By thus utilizing Eleanor and Cherry first we would have secured the yield of only 193 square miles of watershed, controlled by earth dams, instead of the catchment from 459 square miles of the superior Hetch Hetchy watershed, controlled by a massive masonry dam.

As already stated, the total cost would be about the same with Eleanor plus Cherry as for the alternative Hetch Hetchy, but the quantity of water available in the first case would be only about half that from the Hetch Hetchy and there would not be water enough left after supplying the immediate needs of the communities around the bay, to encourage the building up of a temporary garden irrigation service from the surplus water until required for domestic service, as is proposed in the plan now recommended, in which Hetch Hetchy Dam is built first of all and the earth dams at Eleanor and Cherry immediatedly afterward, the Popenaut Dam soon following and the conduit and tunnels along Cherry Creek and North Mountain omitted entirely.

There is some scenic advantage in building the wagon road to Cherry across the low ridge separating it from Eleanor and in building the wagon road to Eleanor by a zig-zag of wide sweep around the bold mountain projection at the north end of the Hetch Hetchy dam, from a half mile to a mile in the length of each leg of the course, making the turns in the little valleys half a mile upstream and down from the dam and obtaining, as the 1,500-foot climb at 5 per cent is made, a series of broad and beautiful outlooks up and down the Tuolumne Canyon and along the two proposed lakes.

Disadvantage of Steel Pipe Lines for Large Supplies Compared With Tunnels

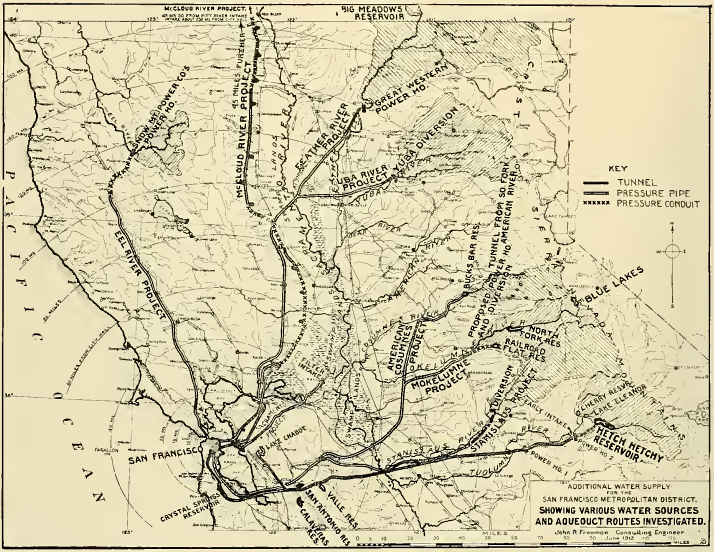
A fundamental technical feature which appears not to have been fully appreciated by some of the amateurs who have discussed future water supply conditions for San Francisco is that there is a critical size above which tunnels are much cheaper than steel pipes, and that there is a practicable minimum limit in lessening the diameter of a long tunnel because of the necessity of having it large enough for men of ordinary size to work comfortably with machine drills, and the necessity of having a long tunnel wide enough for two good size muck cars to pass.

Eight feet in diameter is about the smallest diameter which it is profitable to use in a very long tunnel. An eight-foot tunnel, smoothly lined with concrete, will carry on our common hydraulic gradient of eight feet per mile about 330 million gallons daily. In good sound rock under our average conditions an eight-foot diameter tunnel will cost about $28 per lineal foot, exclusive of profit, heavy plant and overhead and administration charges. This minimum, long tunnel thus costs about $150,000 per mile. An unlined steel pipe of ordinary riveted construction to fit the same cost per mile in this rough country and with a shell one-half inch thick to resist pressures, would have a diameter of about six feet or six and one-half feet, and this pipe would convey less than 100 million gallons daily after a few years old, or less than one-third as much as the smoothly lined tunnel, and the pipe is perishable while the tunnel is permanent.

This principle largely explains why the Freeman project, bringing 400 to 500 million gallons daily to the edge of the San Joaquin Valley, near Oakdale, and from 200 to 240 million gallons daily all the way to San Francisco, costs but little more (and even less when pumping costs are capitalized) than the Grunsky and Manson projects, which brought only 60 million gallons daily into the city; and the same principle explains the vast increase of cost that follows splitting up a main aqueduct line for 200 million gallons, or especially one of 400 million gallons daily capacity, into several branches leading to different reservoirs.

The Steep Gradient Lessens Cost of Hetch Hetchy Aqueduct

On the Sierra division of the Hetch Hetchy aqueduct and also in the long steel pipe crossing the San Joaquin Valley, it is found possible to make use of steep slopes of from 8 to 10 feet per mile, which give high velocity and lessen the necessary diameter and cost of the aqueduct. No other project presents so great advantages as the Hetch Hetchy in this respect.



The Two Groups of Sources Proposed

Note by the above map that the above possible sources divide naturally into two groups:

(1) Tuolumne, Stanislaus, Mokelumne, American Cosumnes.

(2) Eel, McCloud, Feather, Yuba and filtered Sacramento water from Rio Vista.

Note on the map the relative length of the different aqueduct lines and that none except that from the filtration project is shorter than the Hetch Hetchy aqueduct if all have their respective points of diversion similarly carried back into the higher altitudes to secure equal sanitary quality of the water or equal opportunity for power development.

The Tuolumne water taken at Jacksonville or opposite the site of future Power House No. 1 would be equivalent to that of the Stanislaus diversion just above Robinson, shown above.

Note that if the McCloud, Feather and Yuba Rivers water must be filtered because of taking them from a running stream and pumped because of low altitude and delivery at sea level, one might as well pick up these waters at Rio Vista, on the Sacramento River, except for somewhat more serious pollution from sewage of the valley towns. Pollution far more serious is satisfactorily removed by filtration from the water supplies of Washington, London, Hamburg, Albany, Lawrence, Philadelphia, Providence, etc.

This map shows evidence of nothing more direct or with a cheaper aqueduct than the Tuolumne when extra length for going back to equal altitudes and when costs of pumping from low altitudes are given due weight in the comparison.

COMPARING THE ALTERNATIVE SOURCES BY GROUPS

Grouping the Alternative Sources and Aqueducts

Returning to the consideration of other possible sources than the Tuolumne, the opposite map exhibits in outline all of the projects that have been seriously proposed and all that could by any possibility be practiacble for supplying the large quantity of water that will soon be needed by the proposed Metropolitan Water District.

A series of large scale composite maps made up chiefly from the topographic sheets of the U. S. Geological Survey showing each aqueduct route has been prepared for the Advisory Board of Army Engineers.

These possibilities for supplying 200 or 400 or 500 million gallons daily to the San Francisco district are naturally divided into three groups:

First Group

The Upper Tuolumne Group.	Which is sufficient for 400 or 500 million gallons daily.
The Upper Stanislaus. The Upper Mokelumne and Blue Lakes. The Upper Cosumnes and American.	Which possibly could be combined so as to give the 400 or 500 mil. gals. daily by utilizing a large number of small scattered reservoirs and long branch aqueducts or lines of steel pipe.

Each of the above is a mountain source. All are much alike in quality, if taken far enough back toward the crest of the Sierras to have the catchment area in the granite and to be above the region of mining operations. Each could apparently be brought down the mountain slope from the point of diversion, in tunnels or pipes delivering at a sufficient altitude to permit crossing the San Joaquin Valley in a steel pipe of the same diameter as that in the Freeman Plan and thus delivering into the same Coast Range Tunnel and thus reaching the same points and elevations in the cities around the bay as presented on pages 112, 113 and 114; but there are important differences in the merits and costs of these alternative sources which will be discussed later.

Second Group of Alternative Sources

A second group, with many points in common, comprises the Eel River, the McCloud River, the Feather River and the Yuba River, and along with them it is convenient to study the project for a supply of filtered water to be taken from the Sacramento River at Rio Vista by the shortest of all of the aqueducts.

From the Eel River source the direct route would be thru a tunnel under the Golden Gate, but the uncertainties and cost attending this particular point of crossing are such as to exclude this crossing from serious consideration in the absence of extended diamond drill borings, profound geological studies and other studies, the cost of which is not warranted under present circumstances, so if the Eel River is to be considered at all it must come around by Carquinez Straits, like the proposed McCloud and Feather River aqueducts. By reason of distance, difficulty, cost, pumping, power interference and of presenting only half the quantity ultimately required it quickly may be ruled out.

The McCloud, the Feather and the Yuba aqueducts must each cross Carquinez Straits, a mile in width, presumably in a deep tunnel, the quality of rock for which has not yet been explored, or, like the Sacramento filtration project from Rio Vista, must cross the deep, soft peat and silt beds of the Sacramento River over Sherman Island, subject to all of the flood dangers which continually threaten and not infrequently destroy the present dikes of the lower river.

No one of these sources can deliver its water to Lake Chabot, Crystal Springs or the city's reservoirs without pumping, and in the case of the McCloud, the Feather and the Yuba River sources in order to insure the city against interruption from earthquake or accident at the various river crossings, with their slow repairs (as well as for sanitary detention of water taken from a running stream), it would be necessary to establish large storage reservoirs by building the projected Pinole and San Pablo reservoirs for the Oakland group of cities, and to maintain the Crystal Springs Reservoir substantially full and with reduced draft, in order to maintain a proper reserve for San Francisco.

The Cost of Pumping for the Northern Sources

No one of these northern sources gives promise of an amount of water power development in connection with the municipal supply sufficient for lifting this large quantity over the hill of the Diablo Tunnel route into Oakland, or for lifting the water into the distributing reservoirs of San Francisco. In pumping near the city by power developed from the fall of the same water down the mountain slopes each foot of lift requires about three feet of fall.

Even if electric power were available there are large yearly costs for labor, operation, maintenance and obsolescence of electric power stations and pumping stations. **The mere cost of pumping is an enormous handicap against a source which requires pumping as against a gravity supply.**

The pressure in the pipe beneath the harbor should be kept at a minimum as recognized in Mr. Hazen's report upon a filtered supply from the Sacramento in order to minimize the difficulties of crossing in water 60 feet deep, and the tendency of flexible or other joints to leak, and this necessitates large pumping plants located in San Francisco for lifting the water from any one of these sources into the distribution reservoirs and service mains.

The cost of pumping is discussed in the Hazen Report on a filtered supply from Rio Vista, so far as getting the water across the harbor, but no estimate was presented by Mr. Hazen for the further cost of lifting it into the several distribution reservoirs, except to state that some would be pumped to less than 300 feet, and other portions much higher. The probable cost of the city pumping station and machinery for 60 million gallons daily would probably be between $1,500,000 and $2,000,000, this station naturally being more ornate and costly than a pumping station out in the country, as at Antioch.

He finds for his proposed Antioch Station, for a daily average of 60 million gallons, for 280 feet lift and about 4,000 water horsepower, with four 20-million gallon pump units, a probable cost for the pumping machinery of the most efficient type, about	$ 600,000
For steam boilers, about	50,000
For a very cheap and simple station building, foundations, connections, and all auxiliaries, at about $300 per water horsepower	550,000
Total for average of 60 million gallons daily	$1,200,000
or $20,000 per million gallons of average capacity.	
For a delivery of 200 million gallons daily the pro rata cost is	$4,000,000
For a delivery of 400 million gallons daily the pro rata cost is	8,000,000

But beyond this a large allowance must be made for capitalization of operating and maintenance costs and renewals.

For an average lift of 270 feet a cost of 3 cents per million gallons per foot, or $8.10 per million gallons for the whole height.

At 60 mil. gals. per day this amounts to $486 per day.
At 60 mil. gals. per day this amounts to $ 177,400 per year.
At 200 mil. gals. per day this amounts to 591,000 per year.
At 400 mil. gals per day this amounts to 1,182,000 per year.

Capitalized at 6% to also cover depreciation, these amount to:

for 60 million gallons daily	$2,960,000
" 200 " " "	9,850,000
" 400 " " "	19,700,000

or the mere cost of pumping 400 million gallons daily to an average elevation of 270 feet represents interest and depreciation at 6% on an investment of nearly 20 million dollars, which must be progressively credited to the gravity supply as consumption increases, in comparison with a pumped supply.

This disadvantage of pumping is alone enough to turn the scale in favor of the Tuolumne as against the best of the pumped sources, tho built at half its estimated cost!

Sanitary Necessity for Filtration or for Detention Reservoirs

Since each of these three northern sources presents no opportunity for the aqueduct to draft directly from a great reservoir at the outlet of the watershed, in which there would be detention sufficient to destroy the danger of pathogenic germs from the various human activities on their watersheds (which are in each case populated to a much greater extent than the catchments on the Upper Tuolumne) the water must of necessity either be filtered or must be detained in very large reservoirs to be built in the Pinole and San Pablo Valleys, or in the enlarged Lake Chabot.

Objections to Open Storage.

Experience shows that a transparent water like a filtered supply or a ground water supply can seldom be stored in the open sunlight in a warm climate without developing vegetable growths, algae and micro-organisms.

Under the brilliant and remarkably constant sunlight of California, trouble may be anticipated from organic growths that may give rise to bad tastes in waters stored in the lowland temperatures inland from the sea-fog belt. It is desirable to avoid this so far as practicable, and preference should be given a source which has its great storage reservoirs in the cooler mountain altitudes, and with which the city reservoirs can be regarded chiefly as emergency reserves and not a necessary part of the circulation.

The Objectionable Harbor-Crossing

In order to bring water from either the McCloud, Feather, Yuba or from the Sacramento filters into San Francisco, pipes must be laid beneath San Francisco Bay at a point where the water is now about five miles in width, and sixty feet deep for two miles of the way, but this distance could doubtless be shortened to about three and a half miles by means of building an embankment projecting out into the horbor, similar to the Oakland Mole.

This crossing of the harbor presents a very serious objection, altho not an insurmountable one, for there are various expedients, all of them very expensive, by which this crossing can be made and there are many risks of accident while carrying on this work of construction in the harbor.

In each case, at still greater expense, this harbor crossing can be avoided entirely by adding about thirty miles to the length of the San Francisco pipe line and many million dollars to its cost, conveying the water southerly thru Oakland, Hayward, Alvarado to Dumbarton Point and there crossing near the present Spring Valley crossing, where the current, depth and disturbance by navigation are all much less than between Alameda and Potrero Point. This extra length of course involves largely increased cost of pumping to overcome the friction of the longer pipe.

Comparison of the Stanislaus Source With the Upper Tuolumne

As will be seen by the map, the Stanislaus catchment area adjoins that of the Tuolumne and like it extends to the crest of the high Sierras.

It was arranged by the Special Water Committee in May, after the breakdown of Marsden Manson, City Engineer, from overwork, that Mr. C. E. Grunsky investigate this source and his report can be found in Appendix 10. Mr. Grunsky had long been personally familiar with this territory, first as assistant State Engineer, charged with investigating the conservation of the river waters; next as engineer of a special board appointed to study the rivers, and while he was City Engineer, had reported upon its possibilities for water supply to San Francisco eleven years ago. From this experience he apparently had become so impressed with the inferiority of this source in comparison with the Upper Tuolumne that the report of investigation which he placed on file with the Advisory Board of Army Engineers on August 1, 1912, goes into detail and definite quantitative study of the possibilities of this source of supply with much less completeness than may perhaps be necessary for making one understand the situation who is not already as familiar with it as Mr. Grunsky.

His earlier studies were for a supply of 60 million gallons daily for San Francisco alone. He now works out on paper a project from which he believes 200 million gallons daily could be taken to San Francisco after supplying irrigation needs for 143,000 acres, his point of diversion being near Robinson's Ferry, above Coyote Creek, where a low diverting dam would be built at an elevation of about 850 feet above sea level and from which point the water would be carried by tunnel and covered masonry cut and cover conduit to some point on the river southerly from Knight's Ferry, where it would drop to about the same level on the bottom land of Dry Creek, at which the pipe line for crossing the San Joaquin Valley began in his project of eleven years ago, which is shown diagramatically on page 139.

I have relied wholly upon Mr. Grunsky for the information in this case and have not visited the damsites or the aqueduct location, altho familiar with this river at Knight's Ferry.

In order to shorten the Stanislaus aqueduct the diversion of the Stanislaus water is made relatively much farther down the valley than I have proposed in the case of the Tuolumne. In this no advantage is presented by the Stanislaus over the Tuolumne, for the Early Intake of the Hetch Hetchy aqueduct might be placed much nearer the city except for the purpose of safeguarding the purity of the water.

There are no important reservoir sites available for supplying the City of San Francisco from the Stanislaus until one goes much farther back in the mountains than the proposed point of diversion. It is said there are possible reservoir sites on the North Fork near Ramsey and at various points on the headwaters, but each has only a small catchment area. On the Middle Fork there is said to be a reservoir site at Donald Flat, also sites for three small separate reservoirs on small catchments above it, and on the South Fork above Long Camp there are three sites presented but each has small catchment. A study of the topographic maps of the U. S Geological Survey, without visiting the ground, makes it very plain that there is no such opportunity for storage upon the Stanislaus as upon the Tuolumne.

The Stanislaus tributaries and reservoir sites are already largely developed for electric power generation and supply the street railway system of San Francisco, therefore no future opportunity for power generation is open to the city in conection with the aqueduct comparable with the opportunity for developing more than 157,500 horsepower, of 24-hour power, presented at the three consecutive sites along the Hetch Hetchy Aqueduct.

My own preference for developing a Stanislaus project if this were advisable, would be by beginning the aqueduct farther back in the mountains and conserving the head thru tunnels of large size, all the way to the beginning of the San Joaquin crossing, so that this pipe could be put under a sufficient head to carry across the valley on about the same line and grade that I have proposed for delivering the Hetch Hetchy water to the city by simple gravity flow without pumping.

There is no large storage reservoir possible near the point of diversion. Note upon the map of this Stanislaus aqueduct route the long distance of the point of diversion downstream from the region under storage control and note the small catchment area for each reservoir. These facts show up much more plainly on the topographic sheets of the U. S. Geological Survey than on the small scale maps of the Stanislaus catchment here presented.

Mr. Grunsky presents no surveys of reservoir sites and no definite location for tunnels 7½ miles in length or for the masonry conduits 22½ miles in length, none of which appears to have been prospected on the ground. Still for present purposes a tolerably close approximation to its *least* possible cost can be made by assuming that the lay of the land and the geologic conditions are favorable thruout, thus putting this competition in its best possible light.

His estimate of cost for conveying 200 million gallons daily to the city from the Stanislaus aggregates	$39,566,720
of which, however	9,278,000
is comprised by his capitalized cost for operating the pumps at Altamont, for 60 million gallons daily, thus leaving	$30,288,720
as the cost of structures and lands.	

The figure of $39,566,720 for 200 million gallons daily from the Stanislaus is the one that should be compared with the cost of a supply from the Hetch Hetchy of 230 million gallons daily, including tunnels capable of conveying 400 or 500 million gallons daily.

In his estimates the cost of all parts of the work from the Altamont Pumping Station to the point of delivery in San Francisco, comprising about one-half of the whole, are taken from the report of Hunt & Van Norden on the Tuolumne project, dated October, 1911, but with 5 per cent more added for engineering and incidentals than in that report. His estimated cost of reservoirs appears to rest on no definite designs, and like that for aqueduct might prove much greater after definite surveys like those already made for Hetch Hetchy, Eleanor and Cherry.

Altho all assumption like this and all of the unit costs be scaled down to the lowest reasonable limit, the cost cannot be figured down to a point which will make the Stanislaus attractive in comparison with the Hetch Hetchy.

The fact stands out clear and unmistakable that this source is less desirable for the San Francisco Metropolitan Water District than the upper Tuolumne source, by reason of

(1) The much smaller quantity of water available.

(2) The taking of the water from a running stream where it might be subject to typhoid or other infection during a long course, unless filtered or held long in a detention or storage reservoir at the city end.

(3) The small scattered reservoirs far upstream from the point of diversion.

(4) The lower altitude of the proposed point of diversion necessitating more expensive pipe and conduit line across the San Joaquin Valley, unless one places the point of diversion farther upstream, which would increase Mr. Grunsky's estimate of cost.

(5) The fact that the best power sites in this drainage area are already occupied by the important hydro-electric development supplying power to San Francisco's street railway system, and that no future important hydro-electric power development could be available to the city.

(6) Irrigation development is now being actively promoted, and apparently there is less water than land available, whereas on the Tuolumne there appears to be a large surplus after substantially the whole land area possible has already been covered by the irrigation district, with many years of experience to prove out the actual needs and the dangers of over-irrigation. Therefore these Stanislaus irrigation districts are in a position to put up a far more effective opposition to diversion to a distant locality than the Turlock and Modesto districts under present conditions.

(7) In Mr. Grunsky's provisional Stanislaus plan, the water must be pumped over the Altamont Pass, but presumably all pumping could be avoided by delivery into an aqueduct such as I have proposed thru the Coast Range from near Tesla to Irvington for the Hetch Hetchy, save that it would hardly pay to incur the great expense of such a long and difficult tunnel for the smaller amount of water which the Stanislaus can furnish alone. I have not had opportunity for designing and estimating such a project in detail, but I am sure from certain rough estimates that this could by no possibility work out so favorably as on the Tuolumne River.

The Mokelumne River as an Alternative Source to the Tuolumne

The Mokelumne is next in the order of proximity to the Tuolumne after the Stanislaus. The possibility of its use by San Francisco has several times been brought forward by promoters and has received some publicity thru the advertising of the claims by the Sierra and Blue Lakes Water Company, that it could provide the City of San Francisco with an adequate supply of water, coupled with an electric power project from which the income would pay a profit on the whole enterprise.

This Source Several Times Investigated for San Francisco and Rejected

The City Engineer, Mr. Manson, happened to have made brief studies and an adverse report on these Mokelumne sources six years previously, but conformably to the request of Secretary Ballinger began further investigations, comprising surveys of the principal reservoir sites named by the present promoters. Upon Mr. Manson's disability by illness, already referred to, the continuation of the Mokelumne investigation was turned over to Mr. C. E. Grunsky, who had himself also studied this river as a possible source for San Francisco eleven years ago and also had been familiar with many of its features from boyhood, his early home having been in Stockton. Mr. Grunsky's full report, prepared in July, 1912, was filed with the Advisory Board of Army Engineers under date of August 1, 1912, in triplicate, comprising, with appendices, 174 typewritten pages and numerous tables and diagrams. The following is a very brief abstract of the report as filed. Copious extracts from it are presented in Appendix 18.

In the report filed Mr. Grunsky notes that the possibility of supplying San Francisco from these sources was investigated by Col. G. H. Mendell (Municipal Reports 1876-77), and refers to his own investigation of 1901 and to that of these Mokelumne sources made for City Engineer Woodward in 1906.

All of these previous investigations had so plainly brought out the disadvantages of the Mokelumne that Mr. Grunsky evidently was impressed with the unwisdom of spending any large sum of money at the present time for further field work in detail, and so bases his statement upon the facts already on record. Moreover, there was not time for any extensive new field work after Mr. Grunsky was called in to take up the work which Mr. Manson had not completed at the time of his illness. I have not visited this region myself, but have carefully reviewed the data presented by Mr. Manson and Mr. Grunsky.

At my request Mr. Grunsky has since made studies for avoiding the expensive pumping at Altamont, by delivering the water from the Mokelumne into a long, low gradient Coast Range tunnel like that of the Freeman project, and a brief abstract of this later study is also presented in Appendix 18.

The Large Local Need for This Mokelumne Water

One of the adverse facts which stands out most prominently, is that the demands for irrigation upon this watershed will be relatively larger than for neighboring streams and altho certain features of the lay of the land have deferred irrigation and intensive farming, there is now an active awakening on these matters. Mining in this region was so active years ago that many crude storage projects and ditches were completed, but the water rights have largely been kept alive by the diversion of their waters to agricultural use in a comparatively small way, which also has tended to defer a broad comprehensive project for irrigation.

Mr. Grunsky finds that about 100,000 acres of valley land south of the Mokelumne and 100,000 acres north of it will both naturally look to this river for their supply, but states it as certain that if steps should be taken to divert so large an amount as 200 million gallons daily, and particularly if a 400 million gallon diversion to San Francisco were seriously proposed there would be such protest from the land owners that it would be difficult if not impossible to demonstrate that any important diversion would leave enough water to fairly meet the local requirement.

The decisions of the Supreme Court of California adverse to the diversion to a distant region of water needed locally must not be overlooked in this connection.

Lack of Good Reservoir Sites on the Mokelumne

He finds a deficiency in reservoir sites available for supplying both the irrigation needs and the city's needs and that this lack of reservoir sites is so severe that it will be impracticable to fully conserve the Mokelumne waters, and that the occupation of any reservoir site for the city's purposes would distinctly diminish the opportunity for agricultural development. (My own observations of the ordinary topography of the Sierra foot hills leads me to expect that sites for reservoirs at low altitude may be found on thorough search here, as they have been found, for example, northerly from Denver, Colo., which reservoir sites, altho too low and too shallow and too subject to algae and the development of bad tasting organisms under the hot sun of the interior valley for the water supply needs of San Francisco, will be useful in conserving this river's flow for agriculture and flood prevention.)

Impracticability of Future Municipal Power Development from a Mokelumne Aqueduct

Regarding the electric power, Mr. Grunsky notes that there are already various power plants established on the Mokelumne and that the owners of these are already in possession of the most valuable storage sites and that it would be probably impossible to find storage sites that could at reasonable cost be made effective for delivering 200 million gallons daily in addition to the needed agricultural supply.

The following table, taken from Mr. Grunsky's report, is of interest as giving an idea of the known storage possibilities of the Mokelumne watershed without any claim that this list of constructed and possible reservoirs is complete. But it may be fairly assumed that at the present time all of the best sites, except possibly those low in the foot hills, have been found, because the power interests and the irrigation interests have been increasingly active here during the past few years.

TABLE No. 9.

LIST OF RESERVOIRS AND RESERVOIR SITES IN THE WATERSHED OF MOKELUMNE RIVER.

Compiled by C. E. Grunsky.

Name.	Probable height of dam. ft.	Storage, in acre feet.	Storage, billion gals.	Watershed area, sq. mil.
Upper Blue Lake..........	31	6,750	2.20	3.
Lower Blue Lake.........	40	4,741	1.54	2.
Twin Lakes	22	1,425	0.44	.75
Meadow Lake	54	5,615	1.83	5.5
Snow Valley	70	2,180	0.71	1.5
Deer Valley	105	7,200	2.35	12.
Grouse Valley	70	2,380	0.78	5.
Upper Bear River.........	80	6,130	2.00	28.
Lower Bear River.........	70	4.180	1.36	(31.)*
Bummer Flat	35	600	0.20	1.
Pacific Valley	35	980	0.32	4.
Hermit Valley	40	1.120	0.37	24.
North Fork of Middle Fork†	110	5,000	1.63	14
Total of 13 small reservoirs	—	—	15.73	
North Fork†.	325	82,140	26.80	314.
Railroad Flat, South Fork†.	325	69,690	22.70	66. ‡
Grand total	—	—	65.23	

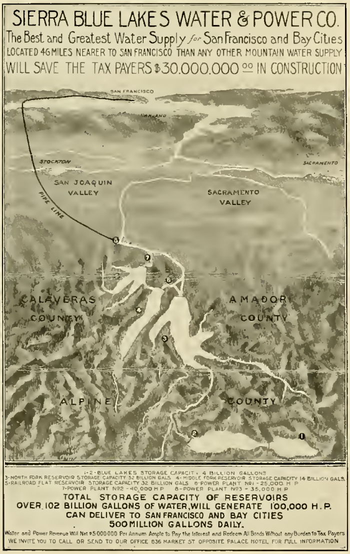
*This included 28 square miles tributary to the Upper Bear River reservoir site.

†Proposed by the Sierra Blue Lakes Water and Power Company.

‡The tributary area can be nearly doubled by means of a feed canal from the Middle Fork.

The two large sites, the last given in the above table, were newly surveyed, under Mr. Manson's supervision, in preparation for the present investigation. Note how much smaller they are found than claimed below.

It is of particular interest to note the very small catchment area controlled by most of these reservoirs and their very small capacity. The aggregate capacity of the 13 small reservoirs is only 15.7 billion gallons, or but little more than Eleanor alone with its low earth dam; and the Railroad Flat and North Fork both together, with the unreasonably large dams projected for them, hold less than half what Hetch Hetchy would contain with a dam of the height shown on page 118. The cubic yards of masonry required for each, the Railroad Flat Dam and the North Fork Dam at the height proposed, with the cost of transportation of cement and supplies together with the relatively small quantity of water that these would yield, plainly make these structures commercially impossible at the present day, and their sites have not been sufficiently explored by test pits to make it certain that dams of these great hights will ever be advisable.


SIERRA BLUE LAKES WATER & POWER CO.

The Best and Greatest Water Supply *for* San Francisco and Bay Cities

LOCATED 46 MILES NEARER TO SAN FRANCISCO THAN ANY OTHER MOUNTAIN WATER SUPPLY

WILL SAVE THE TAX PAYERS $30.000.000 ⁰⁰ IN CONSTRUCTION

1-2-BLUE LAKES STORAGE CAPACITY 4 BILLION GALLONS
3-NORTH FORK RESERVOIR STORAGE CAPACITY 52 BILLION GALS. 4-MIDDLE FORK RESERVOIR STORAGE CAPACITY 14 BILLION GALS.
5-RAILROAD FLAT RESERVOIR STORAGE CAPACITY 32 BILLION GALS. 6-POWER PLANT №1 - 25,000 H P
7-POWER PLANT №2 - 40,000 H P 8-POWER PLANT №3 - 35,000 H P

TOTAL STORAGE CAPACITY OF RESERVOIRS
OVER 102 BILLION GALLONS OF WATER, WILL GENERATE 100,000 H.P.
CAN DELIVER TO SAN FRANCISCO AND BAY CITIES
500 MILLION GALLONS DAILY.

Water and Power Revenue Will Net $5 000 000 Per Annum Ample to Pay the Interest and Redeem All Bonds Without any Burden to Tax Payers

WE INVITE YOU TO CALL OR SEND TO OUR OFFICE 636 MARKET ST OPPOSITE PALACE HOTEL FOR FULL INFORMATION

The Sierra Blue Lakes Promotion

It is of interest to note how utterly insignificant the catchment area of the two Blue Lakes is in view of the prominence given to their name in the promotion of a certain project for water supply which it is desired to sell to the city. Both together hold less than one-tenth part of the contents of the Hetch Hetchy with its low preliminary dam, and the enormous masonry mass of the Railroad Flat dam gives direct storage control for a catchment only about one-eighth part the area of that above the Hetch Hetchy damsite.

It may be of interest to compare the facts as found by Mr. Grunsky with the promoters' claims as set forth in their poster, of which a small photograph is given below, and note how grossly the promoters exaggerate the storage and yield.

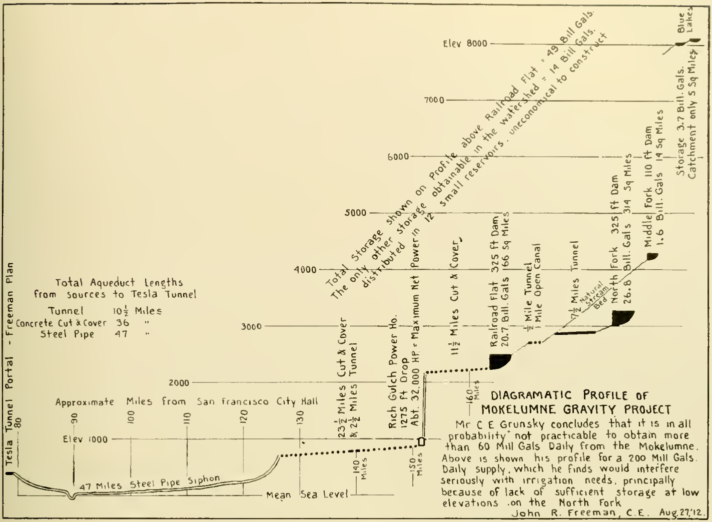
	Promoters claim bil. gals.	Mr. Grunsky finds bil. gals.	
Blue Lakes Storage....	4	3.7	With watershed so small (5 sq. mi.) that yield would be insignificant, and with adverse claims of ownership.
North Fork Reservoir..	52	26.8	With dam of unprecedented h'gt on foundation not fully explored.
Middle Fork Reservoir.	14	1.6	With only 14 sq. mi. of watershed.
Railroad Flat Reservoir	32	22.7	With dam of unprecedented h'gt, and only 66 sq. mi. watershed.

This property appears to largely comprise a miscellaneous lot of old mining ditches and some poor reservoir sites, requiring greater masonry masses than ever yet put into any dam in the world (except the New Croton, in New York), in regions where transportation would make cement very costly, and with no detention reservoir for a sanitary safeguard, and with open ditches to head of pipe line. The "46 miles nearer" is secured by leading water to the pipe in open ditches, much as if Tuolumne water were diverted where the aqueduct crosses the river at Red Mountain Bar.

Probability That Water Remains Available for Filing

Mr. Grunsky calls attention to the fact that because up to the present time only a small part of this river's discharge has been put to beneficial use there would be opportunity, under the laws of California, for San Francisco to secure valid water rights. Altho filings for use within the drainage basin might be valid, the question remains as to their validity for diversion to a distant city, because whatever was thus diverted would surely interfere with future local development, and that in planning new works account must be taken of certain old established priorities and ditches now used for irrigation.

Mr. Grunsky concludes that 50 to 60 million gallons per day would possibly be the maximum that could be diverted from the South Fork to San Francisco without injury to local needs, and that this could probably be secured with the smallest interference with established rights by taking it from the South Fork by means of a high dam storing about 20 billion gallons in the long, narrow reservoir, which would give sufficient detention to remove the danger of pathogenic germs, and would divert from this reservoir in a covered canal to a point near


Elev 8000
7000
6000
5000
4000
3000
2000
Elev 1000
Mean Sea Level
Total Storage shown on Profile above Railroad Flat = 49 Bill Gals.
The only other storage obtainable in the watershed = 14 Bill Gals.
distributed in 12 small reservoirs. uneconomical to construct
Blue Lakes
Storage 3.7 Bill. Gals. Catchment only 5 Sq Miles
Middle Fork 110 ft Dam 1.6 Bill. Gals 14 Sq Miles
North Fork 325 ft Dam 26.8 Bill. Gals 314 Sq Miles
Natural Stream Bed
7½ Miles Tunnel
½ Mile Tunnel 1 Mile Open Canal
Railroad Flat 325 ft Dam 20.7 Bill. Gals 166 Sq Miles
11½ Miles Cut & Cover
Rich Gulch Power Ho. 1275 ft Drop Abt. 32,000 HP = Maximum Net Power
23½ Miles Cut & Cover & 2½ Miles Tunnel
160 Miles
150 Miles
140 Miles
Tesla Tunnel Portal - Freeman Plan
Total Aqueduct lengths from sources to Tesla Tunnel
Tunnel 10½ Miles
Concrete Cut & Cover 36 "
Steel Pipe 47 "
Approximate Miles from San Francisco City Hall
80
90
100
110
120
130
47 Miles Steel Pipe Siphon

DIAGRAMATIC PROFILE OF MOKELUMNE GRAVITY PROJECT

Mr C E Grunsky concludes that it is in all probability not practicable to obtain more than 60 Mill Gals Daily from the Mokelumne. Above is shown his profile for a 200 Mill Gals. Daily supply, which he finds would interfere seriously with irrigation needs, principally because of lack of sufficient storage at low elevations on the North Fork

John R. Freeman, C.E. Aug. 27,'12.

Rich Gulch, which point is substantially on the route of the uncovered canal projected by the Sierra Blue Lakes Water and Power Company in their offer to sell to the city.

From the point thus reached the water would be dropped about 1,275 feet to a power house at an altitude of about 900 feet above sea level and from the tailrace of this power house the water would be delivered into the conduit that would convey it to San Francisco over very much the same line as proposed in the Grunsky and Manson plans shown at the top of page 139, except that the valley crossing is farther north.

The Offer of the Blue Lakes Company

Regarding the offer of the Sierra Blue Lakes Water and Power Company for a supply from the Mokelumne River, Mr. Grunsky presents the following analysis:

That Company is the owner of an old mining ditch which heads on the South Fork at Blue Mountain, and was constructed fifty-five years ago, with a capacity of about 12 second feet. Also, it owns or controls lands on the South Fork at Railroad Flat and upon the North Fork of the Middle Fork, and also holds a reservoir right of way in the Stanislaus Forest Reserve on the North and Main Fork, and also has under its control and offers a reservoir and canal system on the South Fork of the Middle Fork, together with certain other rights of way and undeveloped water rights.

This Company claims it can transfer to the city a good title to all necessary water rights, reservoir sites, rights of way for 60 million gallons per day, and offers to construct and turn the necessary works over to the city completed as far as the beginning of the submerged conduit across San Francisco Bay at Dumbarton Point, for $20,000,000.

Mr. Grunsky analyzes their several offers and reports of February 11, 1911; March 14, 1911, and May 2, 1911, and finds their project would have to be greatly modified and extended to make it acceptable, and as to the cost of carrying it out properly his opinion is indicated by the estimate which he presents in Appendix 18. He notes that some little work has been done to technically hold the various water rights; that on the Licking Fork a concrete dam has been commenced, which at time of inspection was too low to command any storage, and that for some distance upstream the ground had been cleared of brush and timber; that a part of the diverting canal from Middle Fork of South Fork had been constructed; also, that about one-seventh part of the tunnel on conduit line between the Middle Fork and South Fork had been constructed. A camp was formed, maintained and surveyors at work on July, 1912, at the mouth of Blue Creek on the North Fork, and good trails had been constructed from this camp to the south side summit.

At Case Valley, on South Fork of Middle Fork, portions of a washed-out, loose rock fill dam were found. At the head of the Case Valley ditch some four miles below Case Valley, which receives its water in part from the South Fork of the Middle Fork and in part from creeks which it crosses, the ditch was dry and had the appearance of an abandoned mining ditch, but the location was such as to show the feasibility of carrying water on the route suggested. The Case Valley Reservoir is practically negligible.

He notes that the necessary storage on the South Fork, and the desirable storage on the North Fork, can be secured only by dams of unusual height, rising to over 300 feet above the bed of the stream, and that neither damsite is particularly favorable, the gorges not being narrow, and the abutments being covered with more or less soil and rock fragments, the stripping of which will add materially to the known dimensions. The crest length for the Railroad Flat Dam at a height of 300 feet above low water would be about 1,010 feet, and the North Fork at 305 feet above low water would be more than 1,120 feet long. The cubical contents of a masonry dam of gravity section 325 feet high, suitable for the North Fork site would be 605,000 cubic yards, and the storage 26 billion gallons. The masonry is thus 62 per cent more and the storage only about one-fourth part as much as for the projected high Hetch Hetchy Dam shown on page 118, and the catchment area only 70 per cent as much. Thus in every way greatly inferior to the Tuolumne.

He notes further that their various canals from the North Fork Reservoir to the power station should be covered, for sanitary reasons, instead of open, as the promoters propose, in order to cheapen their cost.

As to title to the water of the Blue Lakes themselves, Mr. Grunsky notes that there are possibilities of adverse claims, and that since their total tributary watersheds is less than five square miles, they have very small value for purpose of a municipal water system. Their dams were recently rebuilt by the Pacific Gas and Electric Company.

Mr. Grunsky estimates the cost of supplying San Francisco from the Mokelumne as follows: (The details are set forth at length in Appendix 18.)

For 60 million gallons daily, delivered via Altamont by pumping at about elevation 200 in San Francisco	$30,179,903
For 200 million gallons daily, delivered via Altamont by pumping	$78,642,845

Strictly, for this estimate, the cost of the successive additions of steel pipe should be discounted each to present value, which would reduce the above, but on the other hand certain costs for pumping should be added in capitalized form, and possibly the difficulties disclosed by actual surveys and borings would lead to largely increasing the cost estimated from "paper locations." It is inconceivable that full exploration would cheapen the estimates for these particular structures.

A Gravity Supply from the Mokelumne

Subsequently to the filing of Mr. Grunsky's report above referred to, he prepared a new outline design for a gravity supply from the Mokelumne, starting, as previously, with the Railroad Flat Reservoir and carrying the water at such gradient as to deliver into a low-grade gravity tunnel similar to that by which the Hetch Hetchy aqueduct is carried across the Coast Range in the Freeman plan.

He retains the power house of his previous plan, but instead of conveying the water to a pumping station near Tracy, delivers it to the east end of the Tesla Tunnel of the Freeman project, thru a steel, cement-lined pipe on a hydraulic gradient of about one foot per thousand, under which gradient he finds that a pipe of a net diameter of 63 inches would serve for conveying 60 million gallons and one of 96 inches for conveying 200 million gallons per day.

He states that the unit prices adopted to this modification have been modified to conform as nearly as practicable to those adopted by Mr. Freeman, but states that lack of time forebade going into details. He retained the power plant at Rich Gulch, also a transmission line to San Francisco, concluding this power of 24,000 kilowatts for the 200 million gallons daily was a valuable asset. His estimate of the cost of delivering 200 million gallons daily to San Francisco by this modified aqueduct line is........................$38,412,202.

From which the cost of power and transmission plant should be deducted for comparison with the Freeman project:

For transmission line	$1,922,000.
For power plant suitable for 60 million gallons daily draft (from the Hunt and Van Norden Bear Gulch Power House estimates)	230,120.
Approximate addition for increase to 200 million gallons daily	420,240.
For Power Plant, 200 million gallons daily	$2,572,360.
Plus 15% engineering and contingencies on Power Plant	385,854.
Total to be deducted for Power Plant, for which there is nothing corresponding in Mr. Freeman's Hetch Hetchy estimates	$2,958,214.

$2,958,214.

Net cost of works as estimated very roughly by Mr. Grunsky for works for collecting, storing and conveying 200 million gallons daily from the Mokelumne River at Railroad Flat Reservoir to San Francisco without power plant....$35,453,988.

And delivering it at an elevation of 175 feet above sea level, but including no allowance for pumping to the higher level, to which the Hetch Hetchy can deliver by gravity.

Mr. Grunsky's estimates of cost, while hastily made on broad lines and a design necessarily very crude and incomplete, because of limited time, serve to bring out the great advantage of a gravity flow project, over a project involving pumping over the Altamont pass, and give no hope that the Mokelumne could compete favorably with the Tuolumne, even if we might properly ignore the future irrigation needs.

Conclusions About the Mokelumne Source

Mr. Grunsky's conclusions in brief are as follows:

(1) The occupation and use by San Francisco of any large amount of reservoir space in the watershed of the

Mokelumne River will interfere to a material extent with possible ultimate local development of natural resources.

(2) The Mokelumne River should not be regarded as available to supply the full amount of water that will undoubtedly be required in the future, from remote sources, for use in the bay region. The limit may, for the present, be placed at about 60 million gallons per day.

(3) The cost of storage in large quantity on the Mokelumne River is relatively high.

(4) Any project for the supply of water to San Francisco from the Mokelumne River would probably interfere with vested rights to such an extent that large initial cost for necessary rights and lands should be assumed.

To these I need only add that an inspection of the large scale map makes plain the fact that all of the advantages of damsite, length of aqueduct, quality of storage reservoirs, future water power possibilities, and the great advantage of not having to seek some additional source, at a time when sources equal to those now available are impossible to obtain, are all so plainly and strongly on the side of the Hetch Hetchy and Upper Tuolumne that I do not believe it advisable to expend the $15,000 to $30,000, more or less, which explorations and complete surveys for thoroughly working out the best possible project for a municipal water supply from the Mokelumne would cost.

The American-Cosumnes Source as an Alternative for the Tuolumne

This source is next beyond the Mokelumne in order of proximity and after study of the data on file it is found chiefly of interest for its possibility of combination in the remote future with some other of the high Sierra sources. It can be depended on to yield only about 220 million gallons daily (or half as much as the Upper Tuolumne) so far as shown by the recent studies by Mr. J. H. Dockweiler, C. E., reported in Appendix No. 11.

By no possibility can its water be better than that of the Hetch Hetchy, and the length of the aqueduct plainly can be no shorter than that from the Tuolumne if one goes back toward the headwaters as far in one case as in the other, in order to secure freedom from pollution from mines and other human activities, or in order to secure altitude for hydro-electric power.

The reservoir which it is proposed to build at the point of diversion on the Cosumnes would contain only 18 billion gallons or less than half that in the Hetch Hetchy with its first low dam, and less than one-sixth that of the Hetch Hetchy with its flow line at elevation 3800, notwithstanding the depth of water impounded is nearly the same.

The storage as a whole for the American-Cosumnes project is widely scattered in a large number of little lakes and reservoirs, most of them having very small tributary catchment areas, and obviously much more troublesome and expensive to care for. It is thus plain beyond all doubt or question that this source is less desirable than the Tuolumne.

At the time of the proposal to the city for the sale of these sources, six years ago, an investigation on behalf of the city was made by Mr. Marsden Manson, then in private practice, and by Mr. John R. Price, Assistant City Engineer, in course of which they reported adversely and stated that the data for estimating their yield was meagre; that the then condition of the structures was unsatisfactory for city purposes.

It it not known if the work necessary to maintain possession of the water rights has been kept up.

The fact has weight that engineers of the experience of Mr. Grunsky and Mr. Mardsen Manson, with their many years' familiarity with California rivers, have each after investigation strongly pronounced against the selection of this source and found it inferior to the Tuolumne.

I have not myself personally inspected either the reservoir sites or the proposed aqueduct line, but in forming my opinion have relied upon such facts as are readily obtained from the maps of the U. S. Geological Survey and upon the reports of investigation by Mr. Dockweiler, Mr. Bartell and Mr. Manson, as reported in Appendix No. 11.

This American-Cosumnes project was brought forward conspicuously by the Bay Cities Water Company, William F. Tevis, president, about six or seven years ago, while the city was actively making efforts to secure the Hetch Hetchy. Its promoters then tendered to the city for the price of ten and one-half million dollars, this group of widely scattered reservoirs with connecting canal and appurtenant water rights and priorities. These water rights and reservoirs appear to have been utilized in the early days for mining operations, but had now largely outlived that special usefulness.

There was no accompanying proposition by the promoters to build the aqueduct, 162 miles long, from the Bucks Bar Reservoir, the proposed point of diversion, to the City of San Francisco, but the claim was set forth in the printed report of an address delivered by the Chief Engineer of the Company, at a meeting in the Commonwealth Club in San Francisco on March 13, 1907, concerning the proposition made on April 9 and May 21, 1906, that the whole cost would be about $38,000,000, for 60 to 75 million gallons daily, or about a million dollars less than for the Grunsky Hetch Hetchy project.

The chief argument in favor of this project at that time was that permission could not be obtained by the city for using the Hetch Hetchy.

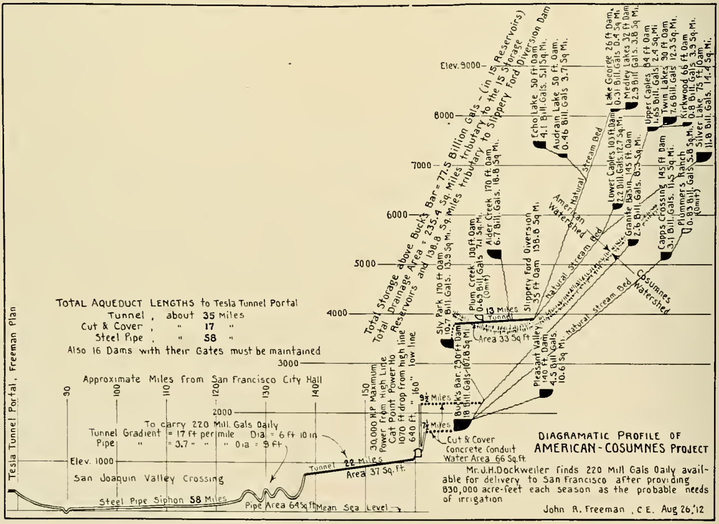
The offer included a proposal to put the dams and canals all in good order and to build certain new dams necessary for developing the total of 60 or 75 million gallons daily, but it was stated that much more than this quantity of water could be obtained.

The report by Mr. J. H. Dockweiler, presented in Appendix No. 11, covers the same American-Cosumnes sources tendered to the city in 1906, and the drawings which he presents are mostly photographic copies of the drawings presented in 1906 by the Bay Cities Water Company. More data upon stream flow is available now and Mr. Dockweiler computes from data that 220 million gallons could be obtained by works that he describes.

I have no information as to the feasability of obtaining a larger quantity from this source at lower points of diversion on either the American River or on the Cosumnes River, but from the appearance of the topographic maps see no reason to expect it and also meet the proper irrigation requirements, and plainly this 220 million gallons will be insufficient to meet the municipal demands that are sure to come before the close of this century.

Since the first aqueduct project worked out by Mr. Dockweiler as a basis for estimating the cost was on substantially the same lines as the aqueduct of the Grunsky and Manson plans, in which pipes were used for the entire length of conduit from the foothills to San Francisco, with pumping over the Altamont Pass, I asked him to prepare a second estimate, in which the lines and the unit costs of the Freeman project should be followed as closely as practicable, delivering the water by gravity flow without pumping.

He has worked this out with as much detail as the scant allowance of time would permit and finds a total cost of $69,210,000 for 220 million gallons daily. Although with more time, more surveys and closer study some better design


Tesla Tunnel Portal, Freeman Plan
TOTAL AQUEDUCT LENGTHS to Tesla Tunnel Portal
Tunnel, about 35 Miles
Cut & Cover, " 17 "
Steel Pipe, " 58 "
Also 16 Dams with their Gates must be maintained
Approximate Miles from San Francisco City Hall
90
100
110
120
130
140
150
160
Elev. 9000
8000
7000
6000
5000
4000
3000
2000
Elev. 1000
To carry 220 Mill. Gals Daily
Tunnel Gradient = 17 ft per mile Dia = 6 ft 10 in
Pipe " = 3.7 " " " Dia = 9 ft
San Joaquin Valley Crossing
Steel Pipe Siphon 58 Miles
Pipe Area 64 Sq ft
Mean Sea Level
Tunnel 22 Miles
Area 37 Sq. Ft.
30,000 H.P Maximum
Power from High Line
Cat Point Power Ho
1070 ft drop from high line
640 ft " " low line
9½ Miles
7½ Miles
Cut & Cover Concrete Conduit Water Area 66 Sq.Ft.
Buck's Bar. 290 ft Dam 18 Bill. Gals-107.8 Sq Mi
Sly Park 170 ft Dam 10.7 Bill. Gals. 13.9 Sq Mi.
Plum Creek 130 ft. Dam 0.69 Bill. Gals 7.1 Sq. Mi. (Omit)
Area 33 Sq Ft
13 Miles Tunnel
Alder Creek 170 ft. Dam 6.7 Bill. Gals. 18.8 Sq Mi.
Slippery Ford Diversion 35 ft Dam 138.8 Sq Mi.
Total Storage above Buck's Bar = 77.5 Billion Gals - (in 15 Reservoirs)
Total Drainage Area = 235.4 Sq. Miles tributary to the 15 Storage Reservoirs and 138.8 Sq. Miles tributary to Slippery Ford Diversion Dam
Echo Lake 50 ft Dam 4.1 Bill. Gals. 5.1 Sq. Mi.
Audrain Lake 50 ft. Dam. 0.46 Bill. Gals 3.7 Sq Mi.
American Watershed
Natural Stream Bed
Lake George 26 ft Dam. 0.31 Bill. Gals 0.4 Sq Mi.
Medley Lakes 32 ft Dam 2.9 Bill Gals. 3.8 Sq Mi.
Lower Caples 103 ft. Dam 2.2 Bill. Gals. 12.7 Sq. Mi.
Granite Basin 145 ft. Dam 2.6 Bill. Gals. 8.3 Sq. Mi.
Upper Caples 84 ft Dam 1.65 Bill. Gals. 2.4 Sq. Mi
Twin Lakes 90 ft Dam 7.6 Bill. Gals 12.3 Sq. Mi.
Kirkwood 66 ft. Dam 0.8 Bill. Gals 3.9 Sq. Mi.
Silver Lake 75 ft. Dam 11.8 Bill. Gals. 14.4 Sq. Mi.
Capps Crossing 145 ft Dam 3.1 Bill. Gals. 11.5 Sq. Mi.
Plummers Ranch 0.83 Bill. Gals 5.8 Sq. Mi. (Omit)
Cosumnes Watershed
Pleasant Valley 140 ft. Dam 4.5 Bill Gals. 10.6 Sq Mi.

DIAGRAMATIC PROFILE OF
AMERICAN - COSUMNES PROJECT

Mr. J.H. Dockweiler finds 220 Mill Gals Daily available for delivery to San Francisco after providing 830,000 acre-feet each season as the probable needs of irrigation

John R. Freeman, C.E. Aug 26,'12

might be worked out, I can see no possibility that this American-Cosumnes source could come any where near the Tuolumne source in economy or efficiency.

In all this matter of alternative sources it has not been possible within the time set for completing this report to analyze and compare these different projects so closely as I would like in the matter of costs. This I regret, as I also regret the lack of opportunity to personally study all of these so-called alternative sources in the field. It would be interesting altho not profitable to present painstaking designs for the most favorable development of each on which the costs could be compared for more completely setting forth their differences to the non-technical, but this would require months of field work and under present circumstances is impracticable and is I believe entirely unnecessary, so plainly are all of the important facts that must control a proper choice shown on the map.

It is worth while to refer to the statements made in previous years regarding the availability of these other sources for all of these water sheds and some others, were carefully considered in turn by Col. Mendel, Mr. Grunsky and Mr. Manson.

The diagrams on the opposite page show the scattered petty character of the storage opportunities for comparison with those of the Tuolumne.

The results of some of these previous examinations are briefly given in the volume of "Reports on the Water Supplies of San Francisco, 1900-1908," published by the City four years ago, in connection with its application for use of the Hetch Hetchy Reservoir site.

Filtered Water from the Sacramento

This project is set forth in such an admirably complete and convincing manner in Appendix 12 that little need be added here, except to note that the cost of 24 million dollars for delivering 60 million gallons daily, with tunnels adapted for the ultimate delivery of three times this quantity, rests upon a much better basis than that of the other estimates for alternative projects.

Mr. Hazen's estimate of twenty-four million dollars for 60 million gallons per day, or sixty million dollars for 180 million gallons of water per day, does not include the cost of a pumping station within the city limits necessary for delivering the water to an average elevation of about 280 feet above sea level, to which it would flow by gravity under the Freeman Hetch Hetchy project, which pumping station would probably add about $1,500,000 to the cost in each successive 60 million gallon plant. The capitalized cost of operating it under conditions of current practice would be not far from 3 cents per million gallons one foot high. For 60 million gallons daily this expense of city pumping would amount to $177,500 per year, which capitalized at six per cent to also cover depreciation, is equivalent to adding an additional $3,000,000 to the cost of Mr. Hazen's project for 60 million gallons daily.

In the ultimate development of 400 million gallons pumped daily, the capitalized cost of pumping at the same rate, would add nearly twenty million dollars to the cost of this method of supply in comparison with one by gravity flow from the mountains.

It may also be noted that our later inquiries have shown that this part of the Coast Range is a difficult one for tunneling.

Filtered San Joaquin Water Temporarily Via Hetch Hetchy Aqueduct

It is also of interest to note on the map accompanying Mr. Hazen's report in Appendix 12, that since his figures demonstrate that in the early years while the additional quantity required is small the filtration project compares very favorably, **it would be entirely feasible to carry the Freeman Hetch Hetchy aqueduct to the point where it crosses the San Joaquin River and place the intake and filtration works at that point and pump the filtered water into the Hetch Hetchy aqueduct for a term of years,** or to pump the raw water to San Miguel reservoir and put in cheap rapid mechanical filters on its outlet for a few years.

This would avoid the troublesome and extremely expensive harbor crossing, but gives a distance from San Francisco to a filtration site where the Hetch Hetchy aqueduct crosses the San Joaquin as measured on Mr. Hazen's map, of about 79 miles as against a distance of 51 miles by the route which Mr. Hazen adopts from Rio Vista to San Francisco. The cost of pumping would be less here because the equivalent of the three stations of Rio Vista, Antioch and the San Francisco low level pumps and middle service pumps all would be concentrated in one station and one lift and the Hetch Hetchy aqueduct tunnels and pipes being designed for much larger quantities, would call for less frictional loss of head.

The fact that the San Joaquin River will undoubtedly deteriorate in quality and quantity for domestic supply with the increase of irrigation would be less important, in view of the intention to abandon this intake after a term of years and proceed to the Hetch Hetchy Valley. At this point the combined flow from the Stanislaus, Tuolumne, Merced and other streams is available, yet so near the tidal waters that no impairment of navigation could follow this diversion.

Were it not probable that a purchase of the Spring Valley works would be effected in the very near future, it might be of interest to study taking the water here temporarily, delivering it to the San Miguel reservoir, possibly placing rapid mechanical filters at the outlet from San Miguel. Such a project would show favorable costs and give excellent water.

Aqueduct from San Joaquin River to San Francisco

From the cost estimates of Appendix 9, we abstract the following as the total cost of an aqueduct from the San Joaquin River to the San Miguel Reservoir, three miles south from the City Hall, of the full size for 400 or 500 million gallons daily for the 30.6 miles of tunnel from Tesla Portal to Irvington Gate House, and of 100 million gallons capacity from Irvington to Redwood, and thence 50 million gallons daily into the city, including contractor's profit, interest during construction and all overhead charges.

San Joaquin River crossing to Tesla Portal, 8.3 miles of cement-lined steel pipe, 7.5 feet net diameter (capacity 240 million gallons daily)	$ 1,211,000.
From Tesla Portal to Calaveras Junction, 27.45 miles of tunnel, 12.8 feet diameter (future capacity 400 to 500 million gallons daily)	10,262,000.
Across Sunol Valley, 0.85 miles of steel pipe, 8.75 feet net diameter	121,500.
From Calaveras Junction to Irvington Gate House, 3.2 miles of tunnel, 12.8 feet diameter (400 to 500 million gallons daily future capacity)	1,132,900.
Total from San Joaquin River to Irvington Gate House	$12,727,400.
From Irvington Gate House to Manifold Gate House, near Redwood City, near Mile 30.9, via Dumbarton, 16.7 miles of steel pipe, all of future capacity of 100 million gallons daily, including Bay Head Crossing	$ 2,682,000.
From Redwood-Crystal Springs Junction to San Miguel Reservoir, 24.3 miles, 4.5 feet diameter cement-lined steel pipe, capacity 50 million gallons daily	1,618,000.
Total for conduit with capacity for delivering in future, 400, 240, 100 and 50 million gallons daily in the respective sections between San Joaquin River and San Miguel Reservoir	$17,027,000.

The above does not include the 50 million gallons daily pipe from Redwood Manifold into Crystal Springs Reservoir. Obviously, this could be reduced a substantial amount by making the 16.7 miles of cement-lined steel pipe across the bay of only 50. million gallons daily capacity instead of 100 million gallons daily capacity, which size is designed for rapidly replenishing Crystal Springs Reservoir by gravity flow from the Tuolumne and also permitting large use of "secondary water rights" at a low price for intensive farming.

With only 50 million gallons daily pumped, which is about 33% more than the present consumption of San Francisco, the velocity in the large pipes from the pumps to Tesla Portal and in the large aqueduct from the Tesla Portal to the Irvington Gate House, also in the pipe of 6.5 feet diameter, thence to Redwood, would all be so small that the total loss of head for the entire distance would be hardly more than 60 or 70 feet and the pumping to the level of the Tesla Portal would deliver the water at 300 feet above tide in the city, so it would supply both the present low service and middle service districts, and by a booster pump located in the city, giving an additional 100 feet of lift, the San Miguel Reservoir could be filled for the supply of the high districts and be maintained as an emergency reserve.

The relatively small additional cost for pumps, rapid filters, San Miguel Reservoir and a small covered filtered water reservoir at about elevation 300, may be inferred from the prices of Appendix 12.

The practicability of this is worth noting, since after the purchase of Spring Valley, in case of delay with proceeding with the aqueduct between the San Joaquin crossing and the Early Intake, and in case of a shortage of water, temporary pumps could be erected at the San Joaquin crossing, filtration omitted, and the water safeguarded by its period of detention within Crystal Springs reservoir or Lake Chabot.

The McCloud River Project

Turning now to the northern group of possible sources, the McCloud River first demands attention.

An abstract of the more important papers relative to taking water from this source exclusive of the construction drawings which were filed with the Advisory Board of Army Engineers upon July 15th, are presented in Appendix No. 13.

The chief attraction of this source is the abundance of brilliantly clear water which flows at most times from the natural storage in the deep deposits of volcanic ash and lava above Bartles from the remarkable geologic formations southeasterly from Mount Shasta and fed also by the melting snows of Shasta.

This water joins the Sacramento in such great and constant volume and, save when clouded by inflow from Mud Creek, is nearly always so attractive in appearance as to impress the observer with its potential value for water supply purposes until he has considered its great distance from San Francisco and that it must successively be carried across the Sacramento River, the Carquinez Straits and the broad part of San Francisco Harbor. Also that of necessity the **McCloud water would arrive at Carquinez Straits and again at the shore of San Francisco Bay at an elevation requiring expensive pumping plants and a perpetual expense for their operations and maintenance, which, for the plant on the San Francisco shore, when capitalized, adds about five million dollars for each 100 million gallons daily, to the cost of the project in comparison with the Tuolumne,** which requires no pumping, but on the contrary itself presents vast possibilities for future power development at exceptionally small cost.

Altho it might at first view seem that a gravity line could be built from the McCloud, it will be found that if this alinement is pushed back westerly on higher ground so as to obtain ground for support high enough to give sufficiently low water pressures to permit the use of a plain or reinforced concrete aqueduct, the line runs into very rough ground, deeply cut by gullies, greatly increasing the cost, and a steel pipe laid on the valley land would run into prohibitive figures when its great length and low hydraulic gradient are considered. Prudence requires that the pressures within the great length of submerged pipe beneath the harbor be kept low, and the same construction methods can not be used here which could be followed in the shorter and more traffic-free crossing between Dumbarton and Ravenswood, where, as in the case of the railroad crossing, all but about 200 feet might be carried on a pile trestle, or on concrete piers 75 feet apart—the pipe forming its own tubular bridge.

Sanitary conditions on the McCloud also demand attention, because there is no opportunity above the intake for a detention reservoir sufficient to remove the danger from disease germs prior to the water entering the conduit and as will be seen by reference to the report of inspection of Mr. C. E. Grunsky, Jr., in Appendix No. 13, there are many possible sources of danger of infection by typhoid patients in connection with the lumbering operations, the summer camps and the considerable permanent population within the catchment area. Mr. Doak's expressions in his proposal, about the superiority of running water to stored water from the sanitary point of view are simply fanciful and about thirty years behind the times, being based on ideas current before bacteriology became a science.

Proper sanitary requirements can be easily designed but, like the capitalized pumping cost, will add largely to the cost estimated by Mr. Doak. Either of two methods of sanitary protection appear feasible. The best is a filtration plant to be located at any convenient point on the line; most conveniently perhaps after the water has crossed Carquinez Straits, or as in the Hazen Report, Appendix No. 12. This filter plant and its operation could be relatively cheap per million gallons of capacity in comparison with ordinary filtering operations, because of the superior clarity of the water and the rapid rate at which it could be properly filtered.

The other method of sanitary safeguard would be by detention within large storage reservoirs for which a site may be found in the Pinole and San Pablo reservoir sites that have been surveyed and are now owned by the People's Water Company, located in the hills northeasterly from Berkeley, or in Lake Chabot, raised as proposed on page 67. This storage would effect the double purpose of a sanitary safeguard and of a reserve for emergencies in case of accident to the long aqueduct or to the electric transmission relied upon for pumping, or to contingencies at the crossing of Carquinez Straits.

Lake Chabot, like Pinole and San Pablo, would be subject to occasional turbidity from floods on the tributary creeks.

But the disadvantage of long storage of clear water in a climate, warm summer and winter, under a brilliant sun, must not be forgotten, nor the tendency to growth of weeds in the shallow flowage, as can be seen in San Francisco from the wharf near the Lake Merced pumping station. In a clear water like the McCloud, which is essentially a spring water or ground water, this tendency is particularly strong and not only weeds but micro-algae and other microscopic growths may come and give rise to tastes like those which have made the water from some of the most important Eastern reservoirs undrinkable at times. Conditions may possibly come with an accidental "seeding" much worse than anything yet experienced on Lake Chabot. In most Eastern reservoirs these bad tastes come infrequently.

The writer suggests in order to show that he is not alone in forebodings of this kind, that those interested read the comments by Mr. Allen Hazen in the recent American Civil Engineers' Pocket Book, page 918. There is no better authority on purification of drinking water than Mr. Hazen.

No arrangement appears feasible by which the McCloud water can be given the advantage possessed in the Tuolumne source of ultimate delivery from a vast detention reservoir with granite walls, in the cold altitude of the mountains where algae growths will flourish less than in the warmer winter and summer temperatures a short distance inland from San Francisco.

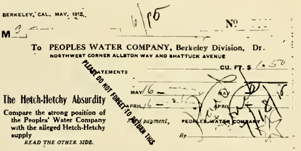
In the case of the Tuolumne, the large emergency reservoirs near San Francisco can be treated purely as reserves and but slightly drawn upon for daily domestic use, while in the case of the McCloud or any other prospective source where the diversion is from a flowing stream or a small intake reservoir far away from the city, the emergency reservoir near the city must always be in the line of circulation if it is to be relied upon for a sanitary safeguard.

If, as a whole, the unit costs used by C. E. Grunsky, Jr., in his estimates of cost for the McCloud project given in Appendix No. 13, be thought too large, in view of Mr. Doak's proposal, or in comparison with the general run of those that I have used for the Hetch Hetchy, it must be remembered that the only prudent course in estimating upon the cost of an aqueduct line which is *merely an unsurveyed paper location* or a mark on a map and where data for details is lacking, is to adopt higher figures than may be used where the line has been laid out on the ground, the formations inspected and the structural features of good roads, cement delivery, local supplies for concrete aggregate, etc., have been all carefully investigated. Also there is room for great difference of judgment as to the method and cost of carrying an aqueduct over the soft peat lands bordering Suisun Bay beneath Carquinez Straits and across the five miles of San Francisco harbor.

The Promotion of Alternative Sources

The presentation of some of the various alternative plans presented in past years when the Hetch Hetchy source has been under active discussion, when closely analyzed, show little merit, has suggested the thought that some of them may have been part of a campaign for the distraction of the attention of citizens from the earnest pursuit of the Hetch Hetchy, like "drawing a herring across the path of the chase." Still it is important to the city that all reasonable possibilities be studied, whether promoted or not.

To illustrate the spirit of opposition to the Hetch Hetchy project by certain interests the following reduced photographic cut of a recent water bill such as sent by the Peoples Water Company to its customers, is presented.



BERKELEY, CAL., MAY, 1912. 6/15

M

No.

To PEOPLES WATER COMPANY, Berkeley Division, Dr.

NORTHWEST CORNER ALLSTON WAY AND SHATTUCK AVENUE

STATEMENTS

CU. FT. $ 1.50

MAY 16

APRIL 16

PLEASE DO NOT FORGET TO RETURN THIS

The Hetch-Hetchy Absurdity

Compare the strong position of the Peoples' Water Company with the alleged Hetch-Hetchy supply

READ THE OTHER SIDE.

Rec'd payment, PEOPLES WATER COMPANY

By

Pricking the Bubble

DO YOU HEAR ANYBODY TALKING HETCH-HETCHY WATER SUPPLY JUST NOW? Its advocates are surprisingly quiet. Why? The stream in Hetch-Hetchy Valley is so low that an active man could jump across it.

BY JULY IT WILL BE A TRICKLING THREAD OF WATER instead of "an inexhaustible supply", as its promoters have heretofore so loudly claimed.

The light snow-fall in the Sierras and this consequent low stage of water, furnish CONVINCING EVIDENCE OF THE ABSURDITY OF SERIOUSLY CONSIDERING THIS SOURCE of water supply for Oakland, San Francisco and other bay cities.

THE ADJACENT IRRIGATION DISTRICTS HAVE THE FIRST CLAIM ON ANY WATERS FROM THIS SOURCE; hence the hope of acquiring a great supply from this source is small. The expenditure of millions in all kinds of expedients can hardly secure the required storage in the few seasons during which the full flow exceeds the needs of the irrigation districts.

As a matter of fact on June 15, the date of this bill, there was 2115 cubic feet per second flowing at the Hetch Hetchy dam site, and on July 1 a flow of 1008 cubic feet per second, 664 cubic feet on July 15 and 275 on July 31. On August 15 the rate of flow was about 161 cubic feet per second, which is about three or four times the maximum quantity ever delivered by the Peoples Water Company.

But it is the water from the 40 billion gallons, or 110 billion gallons and ultimately 171 billion gallons of storage, with all four dams of final height, on which reliance is placed for maintaining the delivery of from 400 to 500 million gallons daily to the cities in dry years.

The Feather River and the Yuba River

The Feather and the Yuba have not been presented by the owners of water rights, but contain some of the most notable opportunities for storage.

The possibilities of the Feather River are set forth in Appendix No. 15, and it is plain that no advantage whatever is found in extending the aqueduct all the way from Rio Vista on the Sacramento to the North Fork of the Feather River if, after all, the water must be both filtered and pumped. The possibilities of supply from the Yuba River are set forth in Appendix No. 16, and as upon the Feather River there is such exposure of the water to possible pollution with no available detention reservoir near the point of diversion that it would require filtration. Morover, its location and distance are such that the water would require pumping near the Sacramento crossing, or after reaching the San Francisco shore.

The filtration project as set forth by Mr. Hazen in Appendix 12 is plainly superior to any project that finds its source in the rivers *farther north than Rio Vista, and which would require filtration* and which is necessarily conveyed by an aqueduct that would deliver at Carquinez Straits or the Sacramento crossing *with but slight elevation above sea level.*

Absence of Reservoir Sites on the Sierra Rivers

The peculiar need of the San Francisco Metropolitan District for the Hetch Hetchy Valley in its plans for the best possible line of domestic water supply development for the long future, comes from the fact that there is no other reservoir site anywhere within reach on the Sierra rivers which approaches this in suitability for storing at high altitudes, a large supply, from a sterile watershed, under conditions that prevent organic growths.

Substantially the whole Sierra region has now been surveyed by the U. S. Geological Survey with a precision and fullness of detail sufficient to disclose all reasonable possibilities of large storage. On studying a set of these maps that have been joined in their proper position, like the set we have prepared for the Advisory Board of Army Engineers, and on tracing each of the important rivers from its mouth to its head waters thruout all of the area within reasonable reach of San Francisco, it will be found how remarkable is the absence of good reservoir sites save in the foot hill region, where, as already stated, the conditions, however admirable for irrigation storage, are not well suited for domestic water supply storage because of the abundant sunshine, the warm winter and summer temperatures in these low foothill valleys, which would doubtless promote luxuriant organic growths, that by their decay would sometimes give bad tastes and bad odors to the water.

Following up each of these rivers carefully on the map it will be found that the canyons on the large streams are remarkably deep and narrow and it can be plainly seen outside of the few well known sites already exploited that storage within them is impracticable by reason of small reservoir areas, great heights of dam and the fact that the silt carried in the lower courses of these rivers would soon fill any such reservoir, just as the La Grange Reservoir has become nearly filled.

On the headwaters of these rivers are a multitude of small lakes and valleys which can be dammed more efficiently than they were by the crude structures of the old hydraulic placer mining days and it is only by utilizing developments of this kind that it has been possible to work out projects on the Stanislaus, Cosumnes and American Rivers.

Save at the Hetch Hetchy, Eleanor, Cherry and Poopenaut group of sites, the reservoir sites unfortunately all lie too near the head of the watershed.

This can be plainly seen by a study of the topographic maps of the United States Geological Survey. Moreover, many of the most available sites have already been occupied for hydro-electric power development.

Although considerable storage capacity might be obtained at the head waters, *storage capacity without catchment area to fill and replenish it, is of small* use.

Large Reservoirs a Necessity on These Sierra Rivers

All of these rivers go nearly dry in summer unless the flood waters from the melting snows are conserved by large reservoir storage. The flow for about half the year is practically nothing, altho at times when the snow is melting, and particularly when its melting is hastened by warm, heavy rains, these mountain streams are torrents, large in volume.

Not only is the shrinkage in volume great from June to August, but also the variation of total runoff in different years is subject to great extremes on these California rivers, and it has become almost a maxim here that a city reservoir system must hold two or three years supply. A reservoir on one of these California rivers to be suitable for domestic supply must be so placed and of sufficient size to catch enough from the brief period of spring flow to give not only a uniform flow during the entire year, but must also be large enough to store a surplus in the years of heavy rainfall for use in years when the rainfall is extremely small. The Crystal Springs Reservoir is an excellent example of this. Therefore, to produce a given rate of flow from a given catchment area, having a given mean annual depth of rainfall, necessitates far greater reservoirs on these California streams than are required under the conditions found in the Eastern states, but most unfortunately the reservoir sites thruout the California Sierras are abnormally few and mostly small. On the Feather River are several large reservoir sites, but on the other rivers except the Tuolumne they are few and mostly very small.

The Yuba River

The Yuba River presents conditions similar to those already described on the Stanislaus, Mokelumne, Cosumnes and American Rivers, as can be plainly seen from the maps of the U. S. Geological Survey. On both branches of the river are many opportunities for building small reservoirs on the headwaters where catchment areas are small.

The South Fork of the Yuba River, in addition to about twenty petty reservoirs and lakes, most of which are more or less under storage control, presents one admirable damsite below the artificial lake Spaulding, near Emigrant Gap, where by means of a dam about 300 feet in height, in a narrow gorge on a most excellent foundation of granite, scraped clean by glacial action, there can be stored 30 billion gallons of water. This reservoir for the same height of dam as the Hetch Hetchy will thus give less than one-third of the Hetch Hetchy storage volume and its catchment area is only about one-fourth as great, and its available delivery correspondingly small.

This site is owned and being utilized by the Pacific Gas & Electric Company, which now has 600 men at work building the dam and a thousand more working on tunnels, power house, etc. This new reservoir will discharge, in addition to its own flood storage, the discharge from about twenty small tributary lakes and reservoirs, the discharge from which has for many years been kept under control by the old mining dams and ditches so that it is still used for both water power and irrigation.

Here, as upon the Feather River, I have in previous years had occasion to study the situation for the owners, and these studies also have impressed me with the superior advantages of the Hetch Hetchy for the peculiar needs of San Francisco. Here on the South Yuba, only the surplus over and above these local needs could possibly be available to the city, and altho it were found that irrigation had no prior demand upon this additional quantity of flood water conserved by the new Lake Spaulding Dam, its rate of discharge must vary in accordance with the power demands, and its amount is not sufficient to warrant its transportation to San Francisco over the long route from the highlands.

Examination of the maps will show plainly that an aqueduct carried back to as high altitude as proposed on the Tuolumne in order to obtain quality, to a reservoir on any branch of the Yuba, would be much longer than that from the Hetch Hetchy.

The Middle Fork of the Yuba, altho containing within its catchment area the Bowman, Fordyce and Faucherie Reservoirs, together with numerous little lakes, has so small a catchment above each and all of its storage sites, that by no possibility could it contribute a quantity to San Francisco large enough to be suitable for the future supply of the San Francisco group of cities.

The conclusions of Mr. C. E. Grunsky, Civil Engineer, who was charged by the special water committee with investigating this source, are set forth in Appendix No. 16.

The Probable Order and Cost of Construction of Hetch Hetchy Works

The following assumes the purchase of the Spring Valley Water Works and is subject to change after further study of the different districts. The work of first necessity will probably be the extension of distributing mains in accordance with the results of a study recently made by the City Engineer already mentioned in Appendix 3, but these extensions, as also the building of the San Miguel Reservoir and various problems of extension to meet the growth in Oakland, Berkeley, San Mateo and other communities, are essentially local problems, for which the solution would of necessity be about the same whatever source was adopted.

The present study is directed more particularly to the supply of water than to its distribution, and until the organization of the Metropolitan Water District has been accomplished our problem chiefly relates to San Francisco.

A New Transbay Pipe

For this, the work of first necessity is the building of the Bay Head section of the aqueduct between Crystal Springs Reservoir, across from Ravenswood to Dumbarton Point, past the Irvington Gate House and into the Sunol Valley.

At present there is but a single pipe leading to the city from all the trans-bay sources, and this pipe is understood to be already taxed to the limit of its carrying capacity. Since nearly half the water which San Francisco now uses comes thru this pipe, and since the practicable sources for any important additional supply are believed to all lie across the bay, the importance of immediately constructing this new pipe is plain. The cost from the Calaveras Junction to the Crystal Springs Reservoir, as estimated in Appendix 9, for a pipe conveying 100 million gallons daily and 3 miles of tunnel near Mission San Jose, large enough for 25 to 50 years to come, is $4,805,000

This cost can be lessened materially by making this pipe of only 50 or 60 million gallons daily capacity instead of the 100 M. G. D. designed to utilize the gravity flow in making possible large areas of truck farming in this region and providing for future growth.

The Calaveras Reservoir

An additional supply of water to feed this new pipe should meanwhile be in progress. The supply that would cost the least in the long run (altho not most attractive in quality by reason of storage in warm climate) would be that obtained by building the proposed Calaveras Dam, which work would probably take two years, altho it might possibly be crowded into a single year since the explorations and designs are practically complete and the situation lends itself to the manufacture and deposit of exceptionally large quantities of cement concrete daily.

Considerably more than one year's ordinary runoff would be required to fill this reservoir, which, like the Crystal Springs, is planned with volume large in proportion to its catchment, with a view to maintaining it principally for an emergency reserve.

The estimated cost of this Calaveras Dam to the full height of 793 feet above mean sea, storing 46 billion gallons, is about $2,500,000

The gagings of Calaveras Creek have been so crude that the yield of its watershed is uncertain. Probably within a year or two after the completion of the dam, with average rainfall and with Alameda Creek diverted into it by a canal, this reservoir would yield an average of 20 million gallons daily thruout the year, possibly more. This quantity would supply the increased demands of the San Francisco District, including whatever may be needed for Oakland, San Mateo and other communities, for a term of perhaps five years. Also, possibly five million gallons daily could be continuously obtained for a few years by deep pumping from the gravels above Pleasanton and Livermore, disregarding the rate of replenishment, and this ground water could be had very quickly in case of shortage.

There are, however, contingencies more or less remote of local interference from the Niles Cone property owners and there is believed to be a strong popular demand for the soft and pure mountain water which may over-ride the fact that the beginning of the large burden of interest on the Hetch Hetchy aqueduct might be deferred five years.

As to the risk of shortage before water could be brought from the Tuolumne if the Calaveras Dam were not built, the present indications are that this would not be serious and that emergency measures would prevent any disastrous shortage. The cycles of extreme low rainfall come only once in every ten to twenty-five years. Crystal Springs Reservoir is now nearly full and alone holds one and a half years' supply at the present rate of consumption. The deeper gravels near Pleasanton could without permanent injury be deprived of their water at a rate more rapid than its annual inflow for a few years, leaving the depletion to be replenished after the aqueduct was extended. The ample storage of the Crystal Springs Reservoir permits time for applying remedies and commonly there can be a quick reduction of 10% in a city's water consumption without injury thru a campaign against water waste; or probably a reduction of about 20 per cent could be had by universal metering, as in Oakland, Berkeley and Alameda last year, which towns were fully equipped with meters within seven months and a saving of 25 per cent effected.

While it appears certain there would be less total expenditure of money by deferring the extension of the aqueduct to the Early Intake while successively building the reservoirs at * Calaveras, Antonio and Valle, also meanwhile drawing to the utmost on the Pleasanton and Livermore gravels, there are advantages on the other side. For example, the superior soft- of Tuolumne water, as shown on page 317, would probably save the metropolitan district about $175,000 per year in soap alone, and five years' pleasure in the use of this softer and purer water for drinking and bathing is worth something to three-quarters of a million people. An abundance of pure mountain water would help attract business to these cities.

Aqueduct Tunnel Sunol Valley to the San Joaquin Valley

This is the most difficult portion of the entire Hetch Hetchy project and will require the longest time to construct, by reason of the deep shafts and the long distance between them, and the time necessary for constructing these 28.3 miles in length of tunnel twelve feet eight inches in diameter and lining it with concrete, sets the limit to the earliest date at which the Hetch Hetchy water could be made available, therefore it is obvious that this portion should be the most vigorously attacked when the extension toward the Sierras is begun.

There is no tunnel on this line more difficult or longer between shafts than the Elizabeth Tunnel of the Los Angeles work, which was holed thru in 40 months. Whether these 28.3 miles of tunnel between Sunol and the San Joaquin are built within three and one-half years or seven years is chiefly a question of organization, plant and good management. The recent developments in electrical haulage in mines have made possible much more rapid progress with long drifts, and on the Elizabeth Tunnel it was found that speed and cost were not affected materially by a distance of two miles from the portal.

While this tunneling is going on the construction of the Sunol siphon and the 8.3 miles of steel pipe between the San Joaquin River and the Tesla Portal should be completed, thus assuring a supply for temporary purposes from the San Joaquin by pumping in case of an emergency.

The confluence of the Stanislaus with the main river near the point of crossing and the entrance of the Merced a short distance upstream assure for some years to come certainty of a supply of water at this point.

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* The available yield from each of these reservoirs is today uncertain. Accurate measurements of the water resources at each of these sites and in the ground water regions should be begun at once by recording stream gages, recording rain gages and the constant work of a skilled hydrographer.

Across the San Joaquin Valley the line should also be pushed to a date of completion coinciding with that of tunnels between Sunol and Tesla.

At the same time work should be going on in tunneling from the easterly edge of the San Joaquin Valley to the Tuolumne crossing at Red Mountain Bar, and simultaneously also the tunnel from Red Mountain Bar to Moccasin Creek should be in progress.

Here at Moccasin Creek it would be feasible to arrest the tunneling for some years and take a supply by means of a temporary side-hill canal, conduit or wood stave pipe projected along the contour line up the Tuolumne to near Rough and Ready Creek, where a low diverting dam would pick up the water released at the storage dams back in the mountains. Such a project would be directly comparable in value and efficiency with several of the alternative projects that have been proposed. The water being delivered into the upper end of the Crystal Springs Reservoir would have far more efficient detention for safeguarding the domestic supply against disease germs than is offered in connection with the McCloud, Stanislaus, Mokelumne, American-Cosumnes, Feather or Yuba rivers.

But it is believed advisable and worth the extra cost to carry the Hetch Hetchy aqueduct farther upstream to the point designated as Early Intake, planning the work so as to complete it to this point at the same time with the Coast Range tunnel between the Sunol Valley and the Tesla Portal and to begin the supply to the cities from the Early Intake. The tunnel from the Early Intake easterly to the Hetch Hetchy Dam should be built as soon afterward as convenient, perhaps within five years, altho it will add nothing to the volume of water obtainable and will improve its quality by preventing turbidity for only a few days in the course of the year. With this completed and with the pipe line modified from the drawing on page 112, as explained below, the cities will then have mountain water by quick transit from the main Hetch Hetchy reservoir, which has not been exposed anywhere in its course to the possibility of contamination or to the growth of such organisms as are promoted in reservoirs by the action of sunlight and warmth.

Cost of Hetch Hetchy Supply

It is estimated that the cost of developing this system step by step as above described will be as follows:

These estimates have been made with a painstaking attention to detail seldom attempted in preliminary work of this character and the figures are also set forth open to the examination of citizens and the promoters of rival projects with uncommon fullness in order that the matter may be fully discussed and every part of the data for these cost estimates made plain.

In reviewing the costs for the various divisions in Appendix 9 it should be clearly kept in mind that several of those divisions set forth alternative projects, only one of which would be adopted and in order that the structural advantages of the more expensive types of aqueduct may be properly balanced against the economics of cheaper types.

The following are estimated costs of the several portions of the work, arranged in order of date and of proximity to the city, altho work will be going on simultaneously in many places all along the line.

The following figures include contractor's profit, headquarters expense, interest during construction and all of the items included in the final figures of the tabulation of Appendix 9, page 300, which see for details and basis.

(a) Steel pipe 4.5 feet net diameter, 24.3 miles long, capacity about 50 million daily varying according to slope, from San Miguel Reservoir or University Mound Reservoir to the Redwood City manifold gate house, estimated cost	$1,861,000
(b) From Redwood City manifold gate house to Irvington gate house, cement lined steel pipe net diameter 6.5 feet, capacity 100 million gallons daily with slope of 0.85 feet per 1,000, or 4.5 feet per mile, built across the flooded marsh lands either on concrete piers or upon an earth embankment, as may prove most expedient on further study and for the mile of crossing at the head of the harbor to be either submerged in a dredged chanel or to be carried on concrete piers above the water level not far from the present line of the railroad trestle to a short submerged section corresponding in location to the railroad drawbridge, total length 16.7 miles, estimated cost	2,682,000
(c) Branch line steel pipe 4.5 feet diameter from Redwood manifold gate house into the head of Crystal Springs Reservoir, about 3.6 miles in length, capacity 50 million gallons daily, under 7.0 feet slope per mile, variable to meet conditions, estimated cost	434,000
(d) From Irvington gate house, 3.2 miles of tunnel 12.8 feet diameter (400 to 500 million gallons daily capacity) under mountain at Mission San Jose to Calaveras Junction in the Sunol Valley	1,133,000
(e) Calaveras Junction across Sunol Valley, 0.85 miles of cement lined steel pipe siphon 8.75 feet net diameter, cost	122,000
Forward	$6,232,000

Note: A wood stave temporary pipe, say 3 feet diameter, could be quickly laid to this point from above Pleasanton to take water temporarily from a new set of wells into the above new transbay pipe, if Calaveras reservoir is not built and a water famine is imminent.

ESTIMATE OF COST OF THE HETCH HETCHY PROJECT

Forward	$6,232,000
(f) From Sunol Valley to Tesla Portal, 27.5 miles in length, 12.8 feet diameter, future capacity 400 to 500 million gallons daily, cost	10,262,000
(g) Cement lined steel pipe, 7.5 feet net diameter, from Tesla Portal to the San Joaquin River crossing, 8.3 miles, capacity 240 million gallons daily with 10 feet slope per 1,000	1,211,000
(h) 36.6 miles of cement lined steel pipe crossing San Joaquin River to tunnel portal southeast from Oakdale, 7.5 feet net diamater, capacity, 240 million gallons daily, under 10 feet drop per mile, cost	6,291,000
(i) Tunneling from San Joaquin Valley to Tuolumne crossing at Red Mountain Bar, 10.25 miles, 12.8 feet diameter, capacity 400 to 500 million gallons daily	3,168,000
(j) Tuolumne River crossing. Steel pipe siphon, cement lined, 10 feet net diameter, 0.4 miles in length with support	182,000

The pump lift from river into tunnel portal here would be 285 feet, but the river is polluted by mine waste from Wood Creek.

(k) Tunnel ten feet diameter, concrete lined, capacity 400 to 500 million gallons daily, 5.55 miles in length, Red Mountain Bar to Moccasin Creek power site	1,463,000
Sub-total from Moccasin Creek power site to the reservoir in San Francisco	$28,809,000

(l) At this point the supply could be temporarily taken from river in case of emergency and delivered into Crystal Springs Reservoir by means of a cheap type of cut and cover conduit 50 million gallons daily capacity, from Moccasin Creek power site to a point on the Tuolumne River near Wards Ferry, 7.8 miles long. The probable cost, including low diversion dam, is estimated at about . . . . $275,000.

A temporary open unlined canal for same distance could be built for less.

Forward	$28,809,000
Forward	$28,809,000
(m) Tunnel from Moccasin Creek to the Early Intake, 10 feet in diameter, all concrete lined, including works at Early Intake and chute at Moccasin Creek, total length 19.5 miles, capacity 400 to 500 million gallons daily, under slope of 8 to 10 feet per mile, cost	5,404,000
(n) Estimated cost of low Hetch Hetchy Dam, storing 40 billion gallons, including preparation of reservoir. Dependable yield after satisfying all irrigation priorities 160 million gallons daily	1,138,000
(o) Cost of easy-grade highway, temporarily occupied by railroad from Roasasco to the Hetch Hetchy Dam, 62 miles	1,288,000
(p) Roads to tunnel shafts on Coast Range divisions, additional	36,000
(q) First installment scenic road in Hetch Hetchy Valley, about 10 miles in length, comprising road on north side of valley to point opposite confluence of Tiltill Creek and on south side of valley upstream to the head of flowage; also easy-grade wagon roads to Lake Eleanor and Cherry Creek, laid out with a view to scenic advantages	306,000
Total cost of supply, varying from maximum of 240 million gallons daily to minimum of 160 million gallons daily in extreme drought, delivered to Irvington gate house overlooking San Francisco Bay, with 50 millions delivered into San Francisco 3 miles from City Hall, and 50 millions into Crystal Springs Reservoir when desired	**$36,981,000**

And also with 60 million gallons daily ready for Oakland, San Jose, etc.

(r) Cement lined steel pipe 4.5 feet in diameter from Irvington gate house delivering 50 million gallons daily as far as the City Hall, Oakland	2,247,000

The above 160 million gallons daily would serve all needs and growth for the communities on both sides of San Francisco Bay for a long time and also provide water enough for San Jose, San Mateo, etc.

The remarkable fact appears that the estimated cost of the Freeman project bringing a minimum supply of 160 million gallons daily, in the dryest year, including scenic road, and permanent highways, and with opportunity conserved for a future vast power development, costs less than any of the 60 million gallon daily plans heretofore proposed, and moreover avoids all the expensive upkeep of pumping stations.

It is this fact that has prompted a careful review of the figures and setting them forth in detail for examination by other engineers.

Desirable Extensions for Utilizing Water Rights, Etc.

Future successive steps for increase of quantity to a dependable minimum of 240 million gallons daily—

(s) Unlined tunnel in granite, 8 feet diameter, from Hetch Hetchy Reservoir to Eleanor and Cherry Reservoirs	1,144,000
(The above diversion may properly precede the building of large dams and can be effected by small earth and rock fill dams giving only 10 or 15 feet head, very cheaply built.)	
(t) Earth dams storing about 50 feet depth of water at Lake Eleanor and Cherry Creeks, exclusive of cost of water rights already paid for	$1,170,000
(u) Low masonry dam for flooding Poopenaut Meadows and giving additional storage to elevation	898,000

The above works will give a dependable supply of 240 million gallons daily delivered to Irvington gate house in dryest years and comprise all of the water supply works needed for the next 30 or 40 years, after which higher dams would be needed; also a second steel pipe across the San Joaquin Valley, with which pipe added 400 million gallons daily could be delivered on the shores of San Francisco Bay.

Expenditures already made by City of San Francisco for lands and water rights at Hetch Hetchy, Eleanor, Cherry reservoirs.	$1,236,000

The value of the opportunity for future power development will far more than provide for extension of tunnel from Early Intake to the Hetch Hetchy Reservoir and for the extension of dams and further development of storage as needed to the full amount of 400 or 500 million gallons daily.

The Loading Applied to Unit Costs

In reading preliminary estimates for this class of work I have sometimes found it hard to make certain that the unit costs for tunnels and aqueducts, at so much per lineal foot, had been properly loaded with various items of general expense which seldom are reckoned into the monthly estimates made in the field while the work is in progress and which partial cost often becomes quoted as the cost of the work.

In order to make plain the extent to which the estimates presented in this report on page 160o have been loaded and to make plain the total cost per lineal foot at which my pipe and tunnel lines have been estimated, I have had the following table prepared, in which the field construction cost is given in the first line and the total cost per lineal foot in the last line, with the various accretions from loading and overhead charges noted in between.

A Prudent Basis of the Estimates

When one takes into account the fact that this work is all figured on the basis of an eight-hour day, from similar work under California conditions, and that the city is in a position to "buy this experience" from men who have spent years on other similar work now drawing to a close, and that 15 per cent. is added over and above the Los Angeles costs in the form of "contractor's profit" and that other assumptions have been made with liberality, I believe it is feasible with good management and wise legislation to build the work within the estimated cost. Unwise legislation and poor management might easily add five million dollars or more.

HETCH HETCHY PROJECT

Total Costs Per Lineal Foot by Divisions for Construction of Principal Structures and for Overhead Charges

	Division 4—Crystal Irvington. Length 22.4 miles or 118,300 feet (including open channel).					Div. 5—Irvington-Calaveras. Length, 3.2 mi., 16,900 lin. ft.	Div. 6—Calaveras-Antonio. Length, 1.95 mi., 10,300 lin. ft.		Div. 7—Antonio-Valle. Length, 6.85 mi., 36,200 feet.	Div. 8—Valle-Moccasin. Length, 80.6 mi., 425,570 ft.									Div. 9—Moccasin-Early Intake. Length, 19.5 mi., 103,000 lin. ft.	
	Tunnel	Steel Pipe.				Tunnel	Tunnel	Steel Pipe.	Tunnel	Tunnel		Steel Pipe.							Tunnel	Steel Pipe.
	10.0 ft. diam. Concrete lined 70 per cent timbered. In hard rock, San Bruno sandstone.	6.75 ft. diam. Concrete lined to 6.5 ft. diam. Approximate average head on pipe, 350 ft.				12.8 ft. diam. Concrete lined. 60.70 per cent timbered. Shales, clays and sandstones.	12.8 ft. diam. Concrete lined. 60 per cent timbered. Sandstones and shale.	9.0 ft. diam. Concrete lined to 8.75 ft. Max. head, 180 ft.	12.8 ft. diam. Concrete lined. 65 per cent timbered. Sandstones, shales, schists, pliocene gravels, etc.	12.8 ft. diam. Concrete lined. 60 per cent timbered. Sandstones, shales, schists, porphyrite clays.	10 ft. diam. Concrete lined. 18 per cent timbered. Serpentine slates, porphyrite.	7.75 ft. diam. Concrete lined to 7.5 ft. net diam. Max. head, 540 ft.						10.0 ft. diam. Concrete lined to 9.75 ft. diam. Max. head, 270 ft.	10.0 ft. diam. Concrete lined. 55 per cent timbered. Schists, shales and hard granite.	10 ft. diam. Concrete lined to 9.75 ft. diam. Max. head, 670 ft.
	15800 lin. ft. 2.99 miles.	100060 lin. ft. 18.9 miles.				16900 lin. ft. 3.2 miles.	5800 lin. ft. 1.1 miles.	4500 lin. ft. 0.85 miles.	36200 lin. ft. 6.85 miles.	155910 lin. ft. 29.5 miles.	29300 lin. ft. 5 54 miles.	228250 lin. ft. 45.2 miles.						2110 lin. ft. 0.4 miles.	95980 lin. ft. 1.82 miles.	1700 lin. ft 3.2 miles.
		57690 feet.	36440 feet.	1050 feet.	4880 feet.							211860 feet.	17,000 feet.	6,230 feet.	2,640 feet.	200 feet.	320 feet.			
		Pipe on Dry Land	Pipe on Embankment.	Pipe on Piles.	Channel Cros'g.								Pipe on Dry Land on Embankment.	Pipe on Overflowed Land on Embankment.	Pipe on Trestle.	Pipe on Bridge.	Submerg'd Crossing.	Siphon Across Tuolumne		
	Per Lin. ft	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft
*(1) Construction cost, labor, materials, plant maintenance, etc. (see foot note a)	$34.50	$16.30	$18.60	$36.90	$77.70	$42.60	$39.10	$20.55	$48.20	$46.70	$32.65	$24.85	$29.90	$32.05	$44.40	$176.00	$466.00	$65.40	$34.50	$60.20
Shaft (or adit) proportion	1.90	....	....	....	....	1.60	1.47	....	2.76	2.90	2.56	....	....	....	....	....	....	....	2.36	....
Accessories, miscellaneous	.62	.62	.62	.62	.62	5.26	1.94	1.94	....	.35	.35	.63	.63	.63	.35	.35	.35	.35	*....	*....
(2) Use of plant (cost, less 40% salvage)	4.37	.24	.24	.24	.24	4.55	4.62	1.11	3.31	3.06	2.68	.26	.26	.26	.26	.26	.26	2.84	3.18	3.88
(3) Roads and trails	.69	.05	.05	.05	.05	.06	.43	.11	.19	.16	.16	.04	.04	.04	.04	.04	.04	.16	.12	.06
(4) & (5) Contractor's bond, liability insurance and transportation of laborers	.50	.03	.06	.58	3.03	.59	.72	.27	.61	.76	.53	.18	.25	.26	.44	2.60	7.38	.76	.36	.44
(6) Total	$42.58	$17.24	$19.57	$38.39	$81.64	$54.66	$48.28	$23.98	$55.07	$53.93	$38.93	$25.96	$31.08	$33.24	$45.49	$179.25	$474.03	$69.51	$40.52	$64.58
(7) Contractor's profit, 15% of Item 6, except Divs. 4, 6 and 8, where percentage is reduced because of large quantity of purchased material in the long pipe lines. Percentage here used is 3% on cost of steel and 15% on remainder of amount of Item 6	6.39	1.62	1.90	5.51	9.25	8.20	7.25	2.20	8.25	8.09	6.84	1.96	2.67	2.82	4.73	26.80	70.90	8.27	6.08	[illegible]
(8) Administration, legal expenses, headquarters, engineering, designing, etc., 3½% of Item 6	1.49	.60	.69	1.34	2.86	1.91	1.69	.84	1.93	1.89	1.36	.91	1.09	1.16	1.59	6.26	16.60	2.43	1.42	2.26
(9) Lands and easements for rights of way	.53	2.64	.19	.19	....	.36	.21	.80	.22	.19	.07	.80	.80	.23	.23	....	....	.15	.22	[illegible]
(10) Total	$50.99	$22.00	$22.35	$45.43	$93.75	$65.13	$57.43	$27.82	$65.47	$64.10	$46.20	$29.63	$35.64	$37.45	$52.04	$212.31	$561.53	$80.36	$18.24	$74.[illegible]
(11) Interest during construction, 4½% for three years on one-half of total cost, or 13½% of Item 10	3.44	1.49	1.51	3.07	6.33	4.39	3.86	1.88	4.42	4.32	3.12	2.00	2.40	2.53	3.51	14.34	37.90	5.42	3.25	5.06
†(12) Total, being entire cost per lineal foot of work fully completed	$54.43	$23.49	$23.86	$48.50	$100.08	$69.52	$61.29	$29.70	$69.89	$68.42	$49.32	$31.63	$38.04	$39.98	$55.55	$226.65	$599.43	$85.78	$51.49	$79.95
Per cent of "Loading" by overhead charges	47 prct	39 pr ct	24 prct	29 prct	28 prct	40 prct	44 prct	32 prct	37 prct	37 pr ct	39 prct	24 prct	25 prct	22 prct	24 prct	29 prct	29 prct	30 prct	40 prct	[illegible] prct

†These items are numbered as they appear in table on pages 302 and 303, Appendix No. 9.
Foot note (a), Construction Cost, is exclusive of administration, heavy plant, contractor's profit, etc.
*Head works, chute, pool, etc., not included here, as they are chargeable to whole project.

SOME LATER DETAILS OF HETCH HETCHY PROJECT

Some Changes from the Project as At First Outlined

Since the first part of this report was filed on July 15th, 1912, there has been opportunity to re-visit the Hetch Hetchy Valley and to review portions of the aqueduct line and to make further study of the various details while reviewing the estimates. The construction roads, the scenic road, the temporary power plant, and the order of building the subsidiary dams have been further developed.

In such a project many of the details cannot be settled until after a year of surveying, and test borings as is stated on page 71, and with one or two years more of study minor changes will constantly arise, but as a whole I believe we can rest the case with the project substantially as outlined in the preceding pages and that the work could safely be authorized at once on these general lines without further study except such as noted on page 71.

An Earlier Poopenaut Lake

On page 60, under date of July 15, I have stated that campers might soon occupy Poopenaut Valley, contemplating at that time that perhaps half a century might elapse before a dam would be built at its outlet, but on recently looking over this valley and examining with greater care into the conditions reported to exist at its dam site, it has appeared that it would be wise to build a low dam here in the near future, possibly lower for the first stage than that with crest of elevation 3460 shown on page 293.

The railroad and wagon road will pass close to the end of the dam; the construction plant could be taken from that released on other parts of the work and here there appears to be an ideal situation for a low dam arched horizontally and containing a minimum quantity of masonry. The long lake here would certainly add to the scenic interest of a tour to the Hetch Hetchy.

The mass curves on page 106 show that large quantities of water would be wasted past the Hetch Hetchy Dam in all but the driest years and a dam at the Poopenaut Valley would help conserve this and by supplying part of the irrigation priorities from this storage, a larger amount could be taken from above the main dam into the aqueduct during the irrigation season.

It is so plain that this reservoir will be useful in the ultimate development of the Tuolumne headwaters for the benefit of San Francisco, that no risk should be run as to adverse water rights and nothing makes the title so secure as long-continued important beneficial use.

It is of interest to glance for a moment at the quantities that would have been wasted over a Hetch Hetchy Dam with the crest at elevation 3800, after the diversion of full quantity of 400 million gallons daily and after fully satisfying the irrigation and other priorities of 2410 second feet. These quantities are taken from the diagram of page 106.

Year	Hetchy Bil. Gals.	Eleanor Bil. Gals.	Cherry Bil. Gals.	Total Waste
1896	49.	0.	8.	57.
1897	117.	46.	44.	207.
1898	0.	0.	0.	0.
1899	0.	0.	7.	7.
1900	10.	0.	8.	18.
1901	128.	10.	57.	195.
1902	45.	0.	30.	75.
1903	72.	14.	46.	132.
1904	142.	35.	82.	259.
1905	58.	03.	17.	78.
1906	294.	46.	118.	458.
1907	273.	62.	108.	443.
1908	0.	0.	0.	0.
1909	123.	11.	65.	199.
1910	63.	19.	37.	119.
1911	278.	45.	97.	420.

Although this water conserved by the Poopenaut Reservoir may be used for irrigation of hillside fruit lands, as suggested on page 34, or temporarily for any other purpose, its control should be kept in the Metropolitan Water District.

Scenic Road

After studying further the problem of the scenic road by means of additional surveys recently made by Mr. W. C. Hammatt, parts of this are found more expensive than at first contemplated, and it appears proper to let the complete development of this follow the complete development of the storage and to build at first only about ten miles of this road, comprising all of that from the "hotel site" northerly across the dam and up to the easterly end of the valley bench, and on the southerly side to extend the road upstream to the extreme limit of flowage.

In this connection it appears that a better wagon road to Eleanor and Cherry may be built somewhat as described on page 155, on easier grades than originally contemplated, which roads will also have an important scenic value as they climb out of the valley and give long views up and down the river and future lakes.

Easier Grades for Highway Into Valley

The main highway into the valley can apparently be worked out on much easier grades than at first supposed feasible. By means of a mile or two of very heavy work near the two dam sites and cuttting deeply into the ledge, it appears feasible to build on a grade not exceeding 2½ to 3 per cent. from the mouth of the South Fork all the way into the Hetch Hetchy Valley and its first use for a railroad bed will give the turns in this road a radius of curvature uncommonly large for a wagon road. From near Second Garrote down into the valley there are possibilities of having a grade nowhere steeper than 4 per cent. and much of the way only 3 per cent., also with easy curvature. A complete survey for this construction road and construction railroad all the way from Rosasco to the Hetch Hetchy, should be made immediately and its construction will be one of the very first matters to claim attention.

Temporary Power Plant

Further study indicates there are possibly two methods better than that proposed on page 73, the first alternative being by building a low rock-fill dam at the outlet of Vernon Lake, which dam would remain to add in future to the scenic attractions of the park by preserving the flow of Wapama Falls to the end of the tourist season. This stored water with the natural flow could temporarily serve construction purposes by delivering through a steel pressure pipe to be run down the face of the cliff off far enough to one side of the falls, so as not to detract from them. This pipe would be painted to harmonize with the face of the cliff or could be given a thin coat of Portland cement plastering and have vines and bushes planted near it, except on the bare face of the cliff.

A second alternative for a power plant would be by following approximately the lines suggested by Mr. Manson for his canal and power plant from Lake Eleanor, but doing the work on a far smaller scale and in a far cheaper manner, as would befit a plant for temporary power only, using an open ditch, like a miner's ditch, to convey some 12 or 15 second feet along the contour of the hill to a power drop on North Mountain, the power house being directly across the river from the Early Intake. To supply this water a low, cheap rock-fill and earth dam would be built, backing up Lake Eleanor only about 10 or 15 feet above its present level.

Concerning Additional Surveys and Development Work

Whenever a favorable decision is reached at Washington, energetic surveying, prospecting, diamond drill boring and road-building should begin, and in view of the large investment which the city has already made and its certain ultimate value, an appropriation of $25,000 to $50,000 might properly be made available at once for the purpose of surveys, road-building and building good cabins and storehouses near each damsite and at convenient points along the wagon road, which should be ready as a base of operations when the active work of drilling and road-building begins. On the city's lands at Portulacca and elsewhere it would seem well to fence the most arable portions and put them in order for growing forage in advance of the beginning of active road building. If the city exchanges them with the Federal authorities for reservoir margins, this work will make them useful for the Forest Service.

IN CONCLUSION

It is but proper to write into the record the fact that notwithstanding two years have elapsed since the order was given for the city to "show cause," etc., this report has had to be prepared under great pressure, to meet a prescribed date, and I desire to record the cheerfulness and zeal with which those who helped in the collection of data and the preparation of plans and estimates have worked twelve and sixteen hours per day and sometimes all night, and the thanks of citizens interested in this project are due to Horace Ropes, C. E., J. H. Dockweiler, C. E., Cyril Williams, Jr., C. E., and their associates. Also to my assistant engineers, Mr. Raymond E. Cranston and Mr. Karl R. Kennison, and my assistant, Mr. Eastwood, for their long hours and strong efforts. Also to the printer, Mr. Andrew Y. Wood, who with compositors and pressmen have put in night work far beyond ordinary demands in the hope that they were helping the city's cause in trying to complete the publication of these reports on the date ordered.

In closing I desire particularly to express my appreciation of the earnestness and faithful desire to help the city's cause of Mr. Marsden Manson, City Engineer, and also to testify to the pleasure of camping in the mountains with one so well versed in knowledge of the forests.

Respectfully submitted,

JOHN R. FREEMAN.

August 29, 1912.

Appendix No. 1.

REPORT ON PROGRESS MADE BY MUNICIPALITIES SURROUNDING BAY OF SAN FRANCISCO TOWARD CO-OPERATION IN FUTURE WATER SUPPLY.

1. *In the Common use of the Hetch Hetchy Source of Water supply.*
2. *By the formation of a Metropolitan Water District.*
3. *A combined City and County Government under the name of "Greater San Francisco."*

By PERCY V. LONG, City Attorney of San Francisco.

Common Use of Hetch Hetchy Water Supply

Immediately after the issuance of the permit of May 11, 1908, by Secretary Garfield, the municipalities upon the east side of the Bay of San Francisco manifested an interest in the proposed source of water supply to be obtained under the terms of that permit. The cities of Oakland and Berkeley have on several occasions officially declared, through their legislative bodies, their interest in this source of supply, and have asserted the rights of their municipalities to a portion of the water to be derived therefrom.

Berkeley

On April 29, 1910, the City Council of the City of Berkeley apponted the Hon. Beverly Hodghead, then Mayor of said City, and Mr. W. F. McClure, a Consulting Engineer, and a member of said Council, as a committee to represent the City of Berkeley upon the hearing of the pending order to show cause. Two resolutions were adopted appointing such committee, which were as follows:

> "BE IT RESOLVED, by the Council of the City of Berkeley as follows·
>
> "That Councilman McClure be, and he is hereby, commissioned to represent the City of Berkeley at the hearing of the application to revoke the so-called 'Garfield Permit" in the Hetch Hetchy matter before the Department of Interior at Washington, on the 18th day of May, 1910."
>
> "BE IT RESOLVED, by the Council of the City of Berkeley as follows:
>
> "That Mayor Hodghead join in the representation to be present at the hearing of the application to revoke the so-called 'Garfield Permit" in the Hetch Hetchy matter before the Department of Interior at Washington on the 18th day of May, 1910, if he is able to attend;
>
> "That the Mayor and Councilman McClure be and they are hereby appointed a joint committee to represent the City of Berkeley in this regard,
>
> "AND BE IT FURTHER RESOLVED, that either of the members of this Committee be and he is hereby authorized and directed to file the claims of the City of Berkeley with the Department of Interior at this time."

Pursuant to the terms of the above resolution, the Mayor and Councilman therein referred to proceeded to Washington and participated in the hearing before the Secretary of the Interior in 1910, as appears from the official record of said hearing.

On November 22, 1910, a further resolution was adopted by the City Council of Berkeley, providing for the appointment of an engineer to assist the City and County of San Francisco in the presentation of its report to the Department of the Interior. Said resolution is copied into the subsequent resolution hereinafter set forth.

On March 7, 1911, a fourth resolution was adopted, appointing engineers under the terms of the resolution of November 22, 1910, which last named resolution read as follows:

> "BE IT RESOLVED, by the Council of the City of Berkeley, as follows:
>
> "WHEREAS, on the 22nd day of November, 1910, the City Council of the City of Berkeley did pass a resolution as follows:
>
> "RESOLUTION NO. 698, N. S.,
>
> "BE IT RESOLVED by the Council of the City of Berkeley as follows:
>
> "That the City of Berkeley, in conjunction with the City of Oakland, or the cities of Oakland and Alameda, appoint an engineer to assist the Board of Engineers of the City and County of San Francisco in the preparation of the report to the Department of the Interior at Washington to be used at the hearing of the order to show cause now pending in that Department for the revocation of the permit heretofore granted by that Department for the use of the Hetch Hetchy Valley as a reservoir site.
>
> "Adopted by the Council of the City of Berkeley, November 22, 1910, by the following vote:
>
> "Ayes—Councilmen Berry, Hoff, McClure, Norton and Mayor Hodghead.
> "Noes—None.
> "Absent—None.
>
> "(Signed) BEVERLY L. HODGHEAD, Mayor.
> "Attest: W. J. SEABORN, City Clerk."
>
> "and that on or about the same date a resolution similar in form was passed by the City Council of the City of Oakland and by the City Council of the City of Alameda;
>
> "NOW, THEREFORE, in pursuance of the above resolution,
>
> "RESOLVED, that J. H. Dockweiler, of Oakland, California, and J. D Galloway, of Berkeley, California, be, and the same are hereby appointed as such engineers, the said J. H. Dockweiler to prepare data upon existing and further needs of water supply for the cities of Oakland, Berkeley and Alameda, and upon the possibilities of existing local sources of supply for said cities, and the said J. D Galloway to prepare data upon the possibilities of reinforcing such local supplies from Sierra Mountains and other outside sources. The proportion of the compensation for such services to be paid by the City of Berkeley shall be fixed by the City Council."

On June 27, 1911, a further resolution was adopted which reaffirmed the belief of the City Council of the City of Berkeley for the necessity of the Hetch Hetchy water supply for the Bay cities and reasserted its right to such use. This last named resolution read as follows:

> "BE IT RESOLVED, by the Council of the City of Berkeley as follows:
>
> "WHEREAS, this Council, in May, 1911, sent two of its members to Washington to represent the City of Berkeley in the hearing before the Department of the Interior on the matter of the revocation of the permit to use Hetch Hetchy Valley as a source of water supply for the Bay Cities, which matter was continued for further hearing, and subsequently engineers were appointed by this City to assist the engineers of San Francisco, in preparing a report upon the above question, and we are now notified by the City Engineer of San Francisco that the Board of Engineers appointed by the United States Government to advise the Department upon the question of the revocation of the said permit will hold session in San Francisco during the month of July, 1911;
>
> "NOW, THEREFORE, BE IT RESOLVED, by the Council of the City of Berkeley that it reaffirms its belief in the necessity of the Hetch Hetchy source of a water supply for the Bay Cities and reasserts its right under the Garfield Grant, and hereby appoints W F McClure, now one of the members of the Council, without salary, in conjunction with such others as may hereafter be named, to represent the City of Berkeley at the hearing before the Board of United States Engineers."

Oakland

On May 2, 1910, the City Council of the City of Oakland adopted a resolution calling upon the Board of Public Works of that city to protect the interests of the city upon the pending order to show cause. Said resolution was as follows:

> "WHEREAS, the Interior Department of the United States has cited the City of San Francisco and other bay cities to show cause why the Hetch Hetchy water grant should not be modified or revoked, and it is necessary in order that the rights and privileges heretofore granted by Secretary Garfield should be preserved intact, the Board of Public Works should properly protect the rights of this city in said grant;
>
> "RESOLVED, That the Board of Public Works be, and it is hereby requested to take such action, in conjunction with the authorities of the other bay cities, as may be necessary and proper to safeguard the interests of this City in such water grant."

Pursuant to the terms of the above resolution the Board of Public Works of the City of Oakland, on May 4, 1910, adopted a resolution appointing the Mayor of Berkeley as representative of the City of Oakland at the hearing before the Secretary of the Interior later that month. This last resolution was as follows:

> "RESOLVED, That, under authority of Council Resolution No. 36,590, Beverly L. Hodghead, Mayor of the City of Berkeley, Cal., be and he is hereby designated as the representative of the City of Oakland in the conference to be held in Washington, D. C., of the Interior Department of the United States and the City of San Francisco and other bay cities."

On November 21, 1910, a further resolution was adopted by the City Council which provided for the appointment of engineers to assist in the preparation of a report to the Department of the Interior to be used upon the hearing of the pending order to show cause. This resolution is set out in full in the next resolution adopted by the Council which was as follows:

RESOLUTION OF MARCH 20, 1911:

> "WHEREAS, on the 21st day of November, 1910, the Council of the City of Oakland adopted its Resolution No. 37,418, reading as follows:
>
> " 'Resolved, That the City of Oakland, in conjunction with the Cities of Berkeley and Alameda, appoint some engineer to assist the Board of Engineers of the City and County of San Francisco in the preparation of the report to the Department of the Interior at Washington, to be used at the hearing of the Order to Show Cause now pending in that Department for the revocation of the permit heretofore granted by that Department for the use of the Hetch Hetchy Valley as a reservoir site.'
>
> "AND WHEREAS, on or about the same date a resolution similar in form was passed by the City Council of the City of Berkeley and by the City Council of the City of Alameda; now therefore be it
>
> "RESOLVED, That J. H. Dockweiler, of Oakland, California, and J. D. Galloway, of Berkeley, California, be and are hereby appointed Engineers in accordance with said resolution; the said J. H. Dockweiler to prepare data upon existing and further needs of water supply for the cities of Oakland, Berkeley and Alameda, and upon the possibilities of existing local sources of supply for said cities, and the said J. D. Galloway to prepare data upon the possibilities of reinforcing such local supplies from the Sierra Mountains and other outside sources.
>
> "Further Resolved, That the compensation to be paid for the services to be rendered by said Engineers be and is hereby fixed at the sum of $4,000.00 and the proportion of said amount to be paid by the City of Oakland is and shall be a pro rata proportion on the basis of population, that is to say, such proportion of said amount shall be paid by the City of Oakland as the population of the City of Oakland is to the combined population of the cities of Oakland, Berkeley and Alameda."

On June 26, 1911, a still further resolution was adopted by the City Council which clearly sets forth the inadequacy of the water supply of the City of Oakland for its future needs; the necessity of a mountain source of supply for that city, and the strong public sentiment in favor thereof; the assertion of the rights of the City of Oakland in the Hetch Hetchy source of supply; the formal declaration of joint action by the two cities of Oakland and San Francisco in securing such supply; and the judgment of the City Council that the voters of the city will join with those of the other cities on San Francisco Bay in providing for the joint acquisition and use of such source of water supply.

This last resolution was as follows:

RESOLUTION OF JUNE 26, 1911:

> "WHEREAS, in line with the policy of this Council and that of the People of the City of Oakland, that their water supply be municipally owned and operated, the preliminary step has been taken to acquire the present water plant, by means of a suit in condemnation, which will be pressed to a speedy conclusion,
>
> "AND WHEREAS, the present water supply plant, begun in the year 1867, is taxed to its full capacity,
>
> "AND WHEREAS, the reports of hydraulic engineers show that all of the available sources of water supply which have been proposed by the Water Company's engineers to augment the

present plant will be taxed to the limit of their production by the year 1920,

"AND WHEREAS, the necessity of procuring a mountain source of water supply has been the subject of numerous public discussions, and as the result thereof public sentiment in said City is strongly in favor of the acquisition of a source of water supply from the Sierra Nevada Mountains,

"AND WHEREAS, the City and County of San Francisco and adjacent cities, which may join with it in obtaining a common water supply had granted to them the Hetch Hetchy Reservoir site for such purpose by a permit of the Secretary of the Interior, dated May 11, 1908, known as the 'Garfield Permit',

"AND WHEREAS, the City of Oakland, with a present population of about 155,000, is one of the adjacent cities referred to in the above permit;

"THEREFORE, BE IT RESOLVED, That such mountain source shall be the Hetch Hetchy Reservoir Site, on the Tuolumne River;

"FURTHER RESOLVED, That the City of Oakland formally joins with the City of San Francisco, for the purpose of securing said water supply;

"AND BE IT FURTHER RESOLVED, That, in the judgment of this Council, the voters of the City of Oakland will join with those of the other cities on the Bay of San Francisco in providing for the joint use of said source of water supply by all of said cities, through the medium of a metropolitan water district to be formed under the terms of the law adopted by the Legislature of the State of California at the session of 1909, or in any other practical method which may hereafter be agreed upon."

San Jose

The City of San Jose is the county seat of the County of Santa Clara and is situated at the southern end of the Bay of San Francisco. It has a population of approximately forty thousand and is the commercial center of the Santa Clara Valley, which is one of the largest fruit producing valleys in California.

On July 8, 1912, the City Council of the City of San Jose adopted a resolution asserting its interest in the Hetch Hetchy Valley source of water supply and its belief that the voters of that City would join in the formation of a Metropolitan Water District. Said resolution reads as follows:

> "WHEREAS, the City of San Francisco is about to submit to the Secretary of the Interior of the United States Government its evidence, in response to an order to show cause why the permit heretofore granted for the use of the Hetch Hetchy Valley as a source of water supply should not be revoked; and
>
> ""WHEREAS, the original permit for the use of said Valley, commonly known as the 'Garfield Permit', granted such use 'when the needs of the City and County of San Francisco and adjacent cities, which may join with it in obtaining a common water supply, may require such further development'; and
>
> "WHEREAS, the City of San Jose is one of the adjacent cities to the City and County of San Francisco; and, in the judgment of this Council, the present water supply of said City of San Jose is not sufficient, either in its present form or by additional development, to meet the necessities of the probable growth of said City;
>
> "IT IS THEREFORE RESOLVED, That the City Council of the City of San Jose does hereby join with the City and County of San Francisco in requesting the continuance and permanency of the aforesaid permit for the use of the said Hetch Hetchy Valley as a source of common water supply for the communities surrounding the Bay of San Francisco; and
>
> "BE IT FURTHER RESOLVED, That, in the judgment of this Council, the voters of the City of San Jose will join with those of the other cities on the Bay of San Francisco in providing for the joint use of said source of water supply by all of said cities, through the medium of a metropolitan water district to be formed under the terms of the law adopted by the Legislature of the State of California at the session of 1909, or in any other practical method which may hereafter be agreed upon."

Redwood City

The City of Redwood City is the county seat and principal municipality of the County of San Mateo, which lies between San Francisco and Santa Clara counties, on the west side of San Francisco Bay.

The subject of a more adequate water supply has been one of frequent discussion and resolutions by improvement associations and other bodies of citizens of San Mateo County. Such resolutions are not included herein for the reason that this report is limited to official actions by legislative bodies of municipalities.

The City Council of Redwood City has adjourned for the summer vacation and, therefore, it has been impossible to obtain the passage of official resolutions by that body. Mr. Marsden Manson, City Engineer of San Francisco, is, however, in receipt of a communication from a majority of the Board of City Trustees of Redwod City in their individual capacities, which read as follows:

> "Redwood City, Cal., July 8, 1912.
>
> "To Mr. Marsden Manson,
>
> "Dear Sir: We, the undersigned, members of the Board of Trustees of the Town of Redwood City, State of California, are severally firm in our belief that ultimately a water supply at all adequate to meet the demands of the municipalities in and around San Francisco Bay, especially San Francisco, as well as our own city, will have to be obtained from the Sierra Nevada Mountains, and especially from Hetch Hetchy, which is the only source not now under adverse control.
>
> "We therefore assure you of our support in the passage of the necessary resolution at our very earliest meeting.
>
> (Signed) "E. H. SAMPSON.
> " "JOS. J. HAHIR.
> " "C. J. HYNDING.
> " "GEO. A. DELEAO."

Mr. Manson is also in receipt of a wire from Mr. George A. Merrill, Mayor of Redwood City, which reads as follows:

> "NIGHT LETTER.
>
> "Keddie, Cal., July 6-7, 1912.
>
> "Marsden Manson,
> "City Engineer, 2110 Gough street,
> "San Francisco, Cal.,
>
> "Cannot be in Redwood Monday, but you are safe to include us in municipalities that will depend on Hetch Hetchy ultimately. Will have your action confirmed later.
>
> GEO. A. MERRILL."

Palo Alto

The City of Palo Alto is in Santa Clara County, north of San Jose, and is the seat of Stanford University.

On July 8, 1912, the City Council of Palo Alto adopted the following resolution:

> "The Council of the City of Palo Alto do Resolve as follows:
>
> "WHEREAS, the City of Palo Alto now has a population of about five thousand, and consumes about four hundred and fifty thousand gallons of water per day; and
>
> "WHEREAS, said City now depends upon sub-surface waters, which have been and are constantly being lowered and are insufficient for the future development of this City;
>
> "NOW THEREFORE, BE IT RESOLVED, That it is the sense of this Council that the City of Palo Alto should be ultimately supplied in whole or in part by the greater supply contemplated from the Hetch Hetchy sources."

Daly City

Daly City is a small and recently formed municipality situated immediately south of San Francisco, upon the west side of San Francisco Bay.

On July 8, 1912, the Town Trustees of Daly City adopted a resolution generally similar to that adopted by San Jose, which resolution reads as follows:

> "WHEREAS, the City of San Francisco is about to submit to the Secretary of the Interior of the United States Government its evidence, in response to an order to show cause why the permit heretofore granted for the use of the Hetch Hetchy Valley as a source of water supply should not be revoked; and
>
> "WHEREAS, the original permit for the use of said Valley, commonly known as the 'Garfield Permit,' granted such use 'when the needs of the City and County of San Francisco and adjacent cities, which may join with it in obtaining a common water supply, may require such further development'; and
>
> "WHEREAS, the City of Daly City is one of the adjacent cities to the City and County of San Francisco; and, in the judgment of this Board of Trustees, the present water supply of said City is inadequate for the present needs of its inhabitants, and also excessive in cost, and such inadequacy of water supply is now retarding the growth of said City,
>
> "IT IS THEREFORE RESOLVED, That the Board of Trustees of the City of Daly City does hereby join with the City and County of San Francisco in requesting the continuance and permanency of the aforesaid permit for the use of the said Hetch Hetchy Valley as a source of common water supply for the communities surrounding the Bay of San Francisco; and
>
> "BE IT FURTHER RESOLVED, That, in the judgment of this Board, the voters of the City of Daly City will join with those of the other cities on the Bay of San Francisco in providing for the joint use of said source of water supply by all of said cities, through the medium of a municipal water district to be formed under the terms of the law adopted by the Legislature of the State of California at the session of 1909, or in any other practical method which may hereafter be agreed upon."

San Mateo

With reference to the City of San Mateo, State of California, there is on file in the City Attorney's office of San Francisco a certificate from Mr. E. S. Moulton, City Clerk of the City of San Mateo, and ex-officio Clerk of the Board of Trustees of said City, in which it is set forth that the question of a water supply to the said city and the inhabitants thereof has been a subject of consideration by the said City for about fifteen years past, and that for about three years past it has taken up a considerable portion of the time of the said Board of Trustees, and that on the 29th day of January, 1912, upon request of a water committee composed of citizens of said City, the Board of Trustees directed the President and Clerk to enter into an agreement with the American Engineering Corporation to undertake certain studies and answer certain questions relative to the procurement of additional water for the said town and the preparation of a statement suitable for presentation to the voters of said City in expectation of a bond election which would describe the present situation of said City as to its water supply from an engineering standpoint, and would include such data as would be appropriate to the subject.

And further, that action was and is being taken by the Board of Trustees with a view of satisfying the public need of said city and inhabitants thereof for a broader and more complete service of water for domestic use.

The certificate contains other matter not relevant to the present discussion and is submitted under the corporate seal of the City by the said E. S. Moulton as City Clerk.

Metropolitan Water District

In 1909 the Legislature of the State of California passed an act entitled, "An Act to provide for the incorporation, organization and management of municipal water districts" (Statutes of 1909, page 1097). A copy of this act is attached hereto as "Appendix No. 2." It provides in general for the formation of a water district, through the initiative of the legislative body of any municipality and the subsequent ratification by the legislative bodies of all municipalities named by the first one in its initial ordinance. These legislative acts are then required to be ratified by a majority of the electors of each municipality at a special election called for that purpose. The powers conferred upon the district are sufficiently broad to enable it to acquire a source of water supply and to furnish water to the municipalities within the district, and the surplus, if any, to territory outside of the district. These powers are to be exercised by a board of directors, upon which board each municipality is to be represented in proportion to the number of its registered voters. The board of directors are required to choose three commissioners, who shall be the executive officers of the district. The district is also given power to raise funds for the purchase of property by the issuance of bonds, if authorized by a two-thirds vote of the electorate at a special election called for that purpose. The distribution of water is left to the several municipalities, the power of the district being limited, with minor exceptions, to the sale of water at wholesale to the municipalities.

Shortly after the passage of the act above referred to, conferences were held between the officials of the City and County of San Francisco and those of the cities of Oakland, Berkeley and Alameda, looking toward the formation of a Metropolitan Water District under the terms of the above act. No definite official action has as yet been taken thereunder for the reason that it was considered advisable to wait for the definite settlement of the rights of the City of San Francisco and adjacent cities in the source of water supply from the Hetch Hetchy Valley before forming such district.

In the meantime, and in April, 1911, a further act, providing for the incorporation and organization and management of municipal water districts was adopted by the State Legislature (Stats. 1911, p. 1290). The powers of the water districts authorized to be formed under this latter act are substantially the same as those specified in the act of 1909. The principal differences between the two acts is that in the latter the proceedings are required to be initiated by a petition signed by at least 25 per cent. of the owners of real property within the boundaries of the proposed districts; and the latter act applies to the formation of a district out of a single county and does not provide for the formation of a district from portions of two or more counties, as is possible under the act of 1909. The latter act contains a saving clause by which the act of 1909 is continued in force. It is therefore possible at the present time to form a Metropolitan Water District under either of these acts.

The municipalities situated in the County of Alameda, on the east side of the Bay of San Francisco, are now engaged in the preliminary steps for the formation of a water district under the terms of the act of 1911, it being the purpose of the Alameda County cities to join in acquiring the existing water works in all such cities, and to operate them for their common benefit under the terms of the last named act. It is expected that the acquisition of the present privately owned plants in Alameda County by public authority will be carried on contemporaneously with the acquisition by the City and County of San Francisco of the privately owned plant now supplying that City, and that when all these municipalities have acquired the various privately owned plants now supplying their cities, that they will join in the formation of a water district for the operation of such plants and the supplementing of the present sources of supply from a common mountain source, to be derived from Hetch Hetchy Valley and Lake Eleanor and adjacent streams.

The favorable attitude of the legislative bodies of the municipalities about the Bay of San Francisco upon the subject of a Metropolitan Water District is set forth in several of the resolutions which are contained above under the discussion of the common use of the Hetch Hetchy source of water supply.

The Greater San Francisco Movement

In the year 1907 an organization was formed by representatives of the various commercial and civic organizations in the communities around the Bay of San Francisco, under the title of the "Greater San Francisco Association," for the purpose of promoting the formation of a single city and county government of all the municipalities surrounding the Bay of San Francisco. The work of this Association has progressed to the extent that it has during the last few months circulated and obtained signatures to a petition which will require the submission to the electorate of the State of California, at the general election to be held in November, 1912, of a constitutional amendment to Section 7 of Article XI of the State Constitution, which will prepare the way for the formation of a consolidated city and county government. Under the terms of the State Constitution as it now exists, it is possible for consolidated city and county governments to be formed out of portions of existing counties, but it is not possible for the whole or portions of two or more counties to join in one common government. The purpose of the constitutional amendment is to make the latter consolidation possible.

Under recent amendments to the State Constitution it is possible for the people of the State to directly propose constitutional amendments by initiative petition without the necessity of submission of the same by the State Legislature. Such petitions must be signed by qualified electors equal in number to 8 per cent. of all the votes cast for all candidates for governor at the last preceding general election at which a governor was elected. The number of signatures required to such a petition is approximately 31,000. The Greater San Francisco Association has obtained approximately 50,000 signatures to its petition. Such signatures have been obtained in the communities surrounding the Bay of San Francisco and also in the County of Los Angeles and in other counties of the State.

It is noticeable that of the membership of the Greater San Francisco Association, only about one-seventh are residents of the City of San Francisco, the remaining six-sevenths residing in other communities surrounding the Bay of San Francisco.

The purposes and accomplishments of this Association are set forth in a letter from its secretary to the City Attorney of San Francisco, recently received, which reads as follows:

> "San Francisco, Cal., July 10, 1912.
>
> "Hon. Percy V. Long.
> "City Attorney,
> "San Francisco.
>
> "Dear Sir: Complying with your request for a statement concerning the origin, purpose and status of the Greater San Francisco movement, I beg to state that the movement was initiated in the latter part of the year 1907 by representatives of the various commercial and civic organizations in the communities around the Bay of San Francisco upon the call of the San Francisco Chamber of Commerce.
>
> "A meeting was held in San Francisco, at which an organization was effected and the present organization known as the Greater San Francisco Association is the result of that meeting.
>
> "The governing body of the Association is an Executive Committee on which are representatives of the five counties which are popularly known as the Bay Counties. All of the larger cities have representatives. San Francisco and Oakland each have five members, Berkeley has three, Alameda has three, and the other communities a lesser number.
>
> "The purpose of the organization is to promote the federation of the communities in the metropolitan areas of San Francisco into a single city and county under a borough system of government. The first step in the movement is to procure the amendment of the Constitution of the State so as to permit communities in different counties to consolidate. For this purpose the Association has drafted an amendment which will be submitted to the voters of the State at the election in November. I en-

close you a copy of the proposed amendment. Upon the adoption of the amendment an act of the Legislature will be required to provide the machinery for ascertaining the wishes of the electors in the various communities proposing to consolidate. When this legislation is enacted, elections will be held in the various communities and ultimately a charter will be framed to be submitted to the voters. If we are successful in each of these steps, the new city and county will be a reality by 1915.

"The sentiment for the consolidation is very strong in every locality, not excepting Oakland, which, because of the hostility of the political ring that has dominated Alameda County and Oakland for many years, appears to be hostile.

"The requisite number of signatures to the petition, which will place the constitutional amendment on the ballot, has been obtained without difficulty.

"As indicating the sentiment, I may instance the fact that less than two years ago the City of Alameda at a general city election adopted a proposition favoring consolidation with San Francisco by a majority of four hundred and forty-four out of a total vote of twenty-five hundred. Shortly afterwards, upon a proposal to annex Berkeley to Oakland, the voters of Berkeley, by a vote of six to one, defeated the proposal for the well-understood reason that they favored consolidation with San Francisco, but not with Oakland.

"The benefits expected to be derived from a consolidation will be a substantial reduction of taxes and the improvement of municipal affairs by giving those whose interests and business are in San Francisco, but who reside out of the limits of the city, participation in its affairs.

"Beyond this is the desire of procuring an adequate and inexhaustible supply of water for the communities about the bay, which San Francisco alone is not able to procure.

"Another result expected to be obtained is improved transportation facilities, which involve the construction of a bridge across the bay.

"On the question of water supply, the enormous growth of the cities about the bay promises to exhaust in a very short time the available supply of water, and unless steps are taken at once to secure a further supply, these communities may in ten years find themselves without an adequate supply of pure, fresh water.

"Trusting that this statement will give you the information desired, I beg to remain,

"Yours truly,

"LESLIE E. BURKS, Secretary.
"Per W. C. SHARPSTEIN."

The proposed constitutional amendment which will be submitted to the electorate in November of this year reads as follows:

"SECTION 7. General laws may provide for the merging and consolidating of contiguous territory of two or more cities, or cities and counties, or counties or any part of any county or counties, containing in the aggregate in the proposed merged or consolidated territory a population of at least 350,000, into one consolidated city and county government. No city or town shall become a part of such city and county unless a majority of the qualified voters of such city or town, voting thereon at a general or special election, shall approve such consolidation and at a subsequent general or special election shall also adopt a proposed freeholders' charter for such new consolidated city and county, nor shall any city or town be divided by such consolidation, nor shall any county be included in or divided by such consolidation, unless a majority of the qualified voters of such entire county voting thereon at a general or special election shall vote in favor thereof. The charter so adopted may provide for a borough system of government, by which the different municipalities so uniting for general municipal purposes shall nevertheless retain and exercise such special municipal powers as the charter may provide. The provisions of this Constitution, applicable to cities, and also those applicable to counties, so far as not inconsistent or prohibited to cities, shall be applicable to such consolidated governments. The provisions of this article as to the removal of county seats and the formation of new counties shall not apply to the formation of such consolidated city and county governments, and general laws may provide for the removal of county seats made necessary by the formation of such consolidated city and county government, and for the change of county boundaries in case the electors of the portion of the territory of any county not included in such consolidated city and county desire to organize as a new county or become a part of an adjoining county. Such new consolidated city and county shall be liable for a just proportion of the existing debts and liabilities of the county or counties included in whole or in part in such new consolidated city and county, and shall be entitled to a just proportion of the property of such county or counties, and until such proportion is determined by law such new consolidated city and county shall be entitled to the use of any property or such county or counties situated within the limits of such new consolidated city and county, and such county or counties shall be entitled to the use of any property of such county or counties situated without the limits of such new consolidated city and county. Such new consolidated government shall also be liable for all the existing debts and liabilities of any municipal corporation merged therein, but provision shall be made for the payment of all outstanding bonds of such municipalities respectively by taxes levied only upon property assessable therefor, and situate at the time of such levy within the territory of such municipalities respectively as such territory existed at the time of such consolidation. General laws may provide for the organization of county governments and for the holding and territorial jurisdiction of Superior Courts in the remainder of any county whenever territory consolidated into a city and county government under the provisions hereof shall include the county seat of any county, such organization of county governments, and such holding and jurisdiction of Superior Courts to continue until such time as the same is otherwise provided for by law. The charter of such new consolidated city and county government shall provide for the places of holding sessions of the Superior Courts and of all inferior courts exercising jurisdiction therein."

Appendix No. 2.

CHAPTER 724.

AN ACT TO PROVIDE FOR THE INCORPORATION, ORGANIZATION AND MANAGEMENT OF MUNICIPAL WATER DISTRICTS.

(Approved April 26, 1909.)

The People of the State of California, Represented in Senate and Assembly, do Enact as Follows:

Municipal Water District

Section 1. A municipal water district may be organized, and incorporated and managed as herein provided, and may exercise the powers herein expressly granted or necessarily implied.

Ordinance, What Must Recite

Sec. 2. When any municipality in the State of California desires to organize such a municipal water district, as herein provided for, the legislative body of any municipal corporation, at any regular meeting of such body, may pass an ordinance reciting:

1. The name of the city adopting the ordinance;

2. That the public interest requires the incorporation of a municipal water district;

3. The names of the municipalities which it is desired to include within the district;

4. The name of the district, which shall include the words "municipal water district."

Copy to Other Municipalities

Sec. 3. Within ten days after such ordinance becomes a law the clerk of the said legislative body adopting the same shall transmit by registered mail a certified copy thereof to the legislative body, or bodies, of the other municipalities named therein, addressed to the clerk thereof.

Approval by Other Municipalities

Sec. 4. Within forty days after the receipt of such certified copy of such ordinance by any municipality named therein the legislative body thereof shall by ordinance either approve or disapprove the said ordinance without alteration or amendment; a failure on the part of any municipality to act as herein provided shall be deemed a refusal to approve of such ordinance.

Copy to Initiating Municipality

Sec. 5. After the passage of said ordinance required to be passed by section 4 hereof the clerk of the municipality acting thereon shall forthwith forward a certified copy of such ordinance to the municipality initiating the proceedings.

Fixing Time for Election

Sec. 6. Within thirty days after the receipt of all the ordinances passed by the municipalities named in the initiatory ordinance, if it shall appear that said initiatory ordinance has been approved by all of the municipalities named therein, the legislative body of the municipality initiating the proceeding shall fix a day for holding a special election in each of the municipalities that have approved of said ordinance, at which shall be sumbitted to the electors thereof the proposition of organizing such municipal water district, and shall also provide for holding a similar election within its own municipality; in case the initiatory ordinance has not been approved by all of the municipalities named therein no further proceedings shall be had, but new proceedings may be taken as provided in section 2.

Conduct of Election

Sec. 7. The date fixed for such special election shall be certified to all of the municipalities which may have adopted the ordinance herein provided for, and the legislative body, or bodies, of such municipalities shall have approved said ordinance shall call and provide for the holding of a special election in their respective municipalities on the day so fixed, and such election shall be held and conducted in manner and form as required by law for the holding of special elections within such municipalities, and the cost in each municipality of holding such election shall be paid by the municipality within which it is held.

Ballots

The ballots used at such election shall contain the words: "Proposition to organize a municipal water district (stating the name)," and the words "Yes" and "No," so placed that a voter may indicate his wish in this connection as either in favor of or against said propositions; such ballots shall be counted

Returns

and returns thereof made by the boards selected to conduct such election in time, form and manner as required by law for the holding of special elections within municipalities and shall be canvassed and the result thereof declared and determined by the board or officers charged with such duties within the municipality holding the election.

Certificate of Result

Sec. 8. Within ten days after the canvass of the votes cast at such election, the board or officers canvassing the same shall certify the result thereof to the legislative body of the municipality initiating the proceedings.

Certificate to Secretary of State

Sec. 9. Within thirty days after the receipt of the certificates showing the result of the election held in the several municipalities, if it appears therefrom that the proposition submitted has been approved by a majority of the votes cast on said proposition in each municipality wherein such election is held, the legislative body of the municipality receiving such certificates shall certify to the Secretary of State the passage of the ordinance provided for in section 2, its subsequent approval by the several municipalities approving the same in manner aforesaid and the result of the elections held as herein provided.

Certificate by Secretary of State

Sec. 10. Upon the receipt of the certificate mentioned in the foregoing section, the Secretary of State shall, within ten days, issue his certificate reciting that the municipal water district (naming it) has been duly incorporated according to the laws of the State of California, and that such district is composed of the municipalities of (naming all the municipalities which have approved at the election such organization). A copy of such certificate shall be transmitted to each of the municipalities comprising such district. From and after the date of such certificate the district named therein shall be deemed incorporated as a municipal water district with all the rights, privileges and powers set forth in this act and necessarily incident thereto.

Informality of Proceedings

Sec. 11. No informality in any proceeding or informality in the conduct of any election, not substantially affecting adversely the legal rights of any citizen, shall be held to invalidate the incorporation of any municipal water district, and any proceeding wherein the validity of such incorporation is denied shall be commenced within three months from the date of the certificate of incorporation, otherwise said incorporation and the legal existence of said municipal water district and all proceedings in respect thereto shall be held to be valid and in every respect legal and incontestable.

Power of Water District

Sec. 12. Any municipal water district incorporated as herein provided shall have power:

1. To have perpetual succession;

2. To sue and be sued, except as otherwise provided herein or by law, in all actions and proceedings in all courts and tribunals of competent jurisdiction;

3. To adopt a seal and alter it at pleasure;

4. To take by grant, purchase, gift, devise or lease, hold, use, enjoy, and to lease or dispose of real and personal property of every kind within or without the district, necessary to the full exercise of its powers;

5. To acquire, or contract to acquire, lands, rights and privileges, and construct, maintain and operate conduits, pipe lines, reservoirs, works, machinery and other property useful or necessary to store, convey, supply or otherwise make use of water for the benefit of the district;

Power of Water District

6. To sell water under the control of the district to the municipalities comprising the same without preference to such municipalities; and it may, whenever there is a surplus above that which may be required by such municipalities, sell, or otherwise dispose of such surplus outside of the district to persons, firms, public or private corporations;

7. To have and exercise the right of eminent domain and in the manner provided by law for the condemnation of private property for public use, to take any property necessary to supply the district or any portion thereof with water, whether such property be already devoted to the same use or otherwise, and may condemn any existing water works or system, or any portion thereof owned by any person or corporation. In proceedings relative to the exercise of such right, the district shall have the same rights, powers and privileges as a municipal corporation;

8. To borrow money and incur indebtedness and to issue bonds or other evidences of such indebtedness; also to refund or retire any indebtedness or lien that may exist against the district or property thereof;

9. To cause taxes to be levied for the purpose of paying any obligation of the district;

10. To make contracts, to employ labor and do all acts necessary for the full exercise of the foregoing powers.

Sec. 13. The powers herein enumerated shall, except as herein otherwise provided, be exercised by a board to be known as the board of directors of the named municipal water district. Such board shall be composed as follows:

1. The mayor, or president of the board of trustees of each municipality comprising the district shall be, ex-officio, a member of said board.

2. Each municipality having five thousand legal and registered voters shall choose by and from the members of its legislative body one additional director, and each municipality for each and every ten thousand legal and registered voters over five thousand shall choose by and from the members of its legislative body one additional director, all of whom shall serve during the pleasure of the body making the appointment; provided, that if such members do not desire to serve as such directors, said legislative body may choose any other person who is an elector and resident of such municipality. The number of legal and registered voters in each municipality on the first day of November, 1908, and every four years thereafter shall be taken as the basis for determining the representation of such municipality in the board of directors.

Meeting of Board of Directors

Sec. 14. The legislative body of the municipality initiating the proceedings for incorporating the district shall fix a time and place for the first meeting of the board of directors, which shall be within thirty days from the date of the incorporation of the district.

Commissioners

Sec. 15. At such meeting of the directors, or at such time to which the proceedings may be continued, the board of directors shall choose three commissioners who shall constitute the commissioners of the named water district, but no director shall be eligible to appointment to such commission. The said commissioners shall have the power to make and enter into all contracts, appoint a secretary, who may be a member of the commission, and such other assistants and employes as may be necessary for the exercise of the powers of the district, to fix their compensation, prescribe their duties and remove any appointee at pleasure, and to generally manage its affairs, subject to such restrictions as the board of directors may impose. The commissioners shall receive such compensation as the board of directors shall determine and shall serve during its pleasure.

Directors, Organization and Per Diem

Sec. 16. The board of directors shall elect one of its number president, adopt rules of procedure and fix a time and place for holding regular meetings. The secretary of the commission shall act as secretary of the board of directors. The directors shall receive for each day's attendance at the meetings of the board their necessary expenses of attending the meeting and shall receive no other compensation.

Commissioners' Organization

Sec. 17. The commissioners shall elect one of its members president, who shall sign all contracts on behalf of the district and perform such other duties as may be imposed by the commissioners or the board of directors. They shall appoint an auditor, who shall not be a member of the board of directors, and who shall be charged with the duty of installing and maintaining a system of auditing and accounting that shall completelv and at all times show the financial condition of the district. He shall draw warrants to pay demands made against the district when such demands have been first approved by at least two of the commissioners.

Funds of District

The commissioners shall also designate a depositary or depositaries to have the custody of the funds of the district, all of which depositaries shall give security sufficient to secure the district against possible loss, and who shall pay the warrants drawn by the auditor for demands against the district under such rules as the directors may prescribe.

Bonded Indebtedness

Sec. 18. Whenever the board of directors deem it necessary for the district to incur a bonded indebtedness it shall, by resolution, so declare and state the purpose for which the proposed debt is to be incurred and the amount thereof, and shall direct the commissioners to take, or cause to be taken, such proceedings as may be necessary to incur such debt and in the manner herein provided.

Duty of Commissioners

Sec. 19. The commissioners shall adopt a resolution reciting the adoption of the resolution mentioned in the foregoing section, state the proposition to be submitted to the electors, the amount of debt proposed to be incurred, the maximum term the bonds proposed to be issued shall run before maturity, which shall not exceed forty years, and the maximum rate of interest to be paid, which shall not exceed five per cent per annum.

Fix Date of Election

They shall fix a date upon which an election shall be held for the purpose of authorizing said bonded indebtedness to be incurred, and shall transmit a certified copy of the resolution fixing such date to the officers or board having charge of the conduct of elections of each municipality comprising the district. It shall be the duty of such board or officers in each municipality to provide for holding such special election on the day so fixed and in the manner and form as special elections are held and conducted within the municipality.

Notice of Election

Such board or officers shall give notice of the holding of such election, which notice shall contain the resolution adopted by the commissioners of the water district, the location of polling places and the names of the officers selected to conduct the election, which shall consist of one judge, one inspector and two clerks. Such notice shall be published for two weeks in a newspaper published in each municipality, which paper shall be designated by the commissioners of the water district, or if there is no newspaper printed in any municipality, then by posting such notice in three public places therein. All the expenses of holding such election shall be borne by the district and shall be paid or credited to each city upon the filing of a verified claim therefor with the secretary of the commission. The returns of such election shall be made, the votes canvassed and the results thereof ascertained and declared as in case of other special elections within such municipalities. The board, or officers, declaring the results of such election shall certify such result to the commissioners of the water district. No irregularities or informalities in conducting such election shall invalidate the same, if the election shall have otherwise been fairly conducted. In all respects not otherwise provided for herein said election shall be called, managed and directed as is by law provided for special elections in the municipality in which such election is to be held.

Form of Bonds.

Sec. 20. If from such returns it appears that more than two-thirds of the votes cast at such election were in favor of and assented to the incurring of such indebtedness, then the commissioners may, by resolution, at such time or times as they may deem proper, provide for the form of such bonds and for the issuance of any part thereof, as may sell or dispose of the bonds so issued at such times or in such manner as they may deem to be to the public interest.

Status of Bonds

Sec. 21. Any bonds issued by any district are hereby given the same force, value and use as bonds issued by any municipality, and shall be exempt from all taxation within the State of California.

Power to Construct Works

Sec. 22. The commissioners shall have power to construct works across any stream of water, watercourse, street, avenue, highway, railway, canal, ditch, or flume which the route of said works may intersect or cross, provided such works are constructed in such manner as to afford security for life and property, and said commissioners shall restore the crossings and intersections to their former state as near as may be, or in a manner not to have impaired unnecessarily their usefulness. Every company whose right of way shall be intersected or crossed by said works shall unite with said commissioners in forming said intersections and crossings and grant the rights therefor. The right of way is hereby given, dedicated and set apart to locate, construct and maintain said works over and through any of the lands which are now or may be the property of this State, and to have the same rights and privileges appertaining thereto as have been or may be granted to the municipalities within the State.

Control of Distributing Systems

Sec. 23. The commissioners shall have no supervision or control of any of the distributing systems of the several municipalities, but the distribution of water in said municipalities, the fixing of rates and collecting of charges therefor shall be under the exclusive supervision and control of each such municipality, and the control of the district shall end with the delivery of water to the several municipalities at the point of delivery by said district; provided, that until a municipality shall acquire a distributing system the district may own and lease the same to the municipality upon such terms as may be mutually agreed upon.

Estimate of Cost of Organization

Sec. 24. Immediately after the organization of the board an estimate may be prepared of the probable amount of water that will be used by the several municipalities comprising said district, which estimate shall be based upon the population of said municipalities, and thereafter the board may, in lieu of the other methods of procuring funds herein provided, notify the several municipalities of the estimated probable cost of the organization and conduct of such district, exclusive of the purchase of lands and the construction of works, canals and reservoirs, and the proportionate amount payable from each of such cities, whereupon each of such municipalities shall be required to contribute to said district its proportionate amount of the cost of organization of said district, provided that the sums so paid by each of such municipalities shall be credited to the municipality making the payment, and the same deducted from the charge for water first delivered to said municipality as herein provided.

Water Rates.

Sec. 25. The commissioners, in the furnishing of water to any municipality, shall fix such rate as will pay the operating expenses of the district, provide for repairs and depreciation of works owned or operated by it, pay the interest on any bonded debt, and, so far as possible, provide a sinking or other fund for the payment of the principal of such debt as it may become due; it being the intention of this section to require the district to pay the interest and principal of its bonded debt from the revenues of the district.

Tax to Cover Bonded Debt

Sec. 26. If, from any cause, the revenues of the district shall be inadequate to pay the principal or interest on any bonded debt as it becomes due then the board of directors may cause a tax to be levied for that purpose as herein provided.

Tax Rate to be Levied

Sec. 27. That the board of directors shall require a report from the several municipalities forming the district, showing the amount of the assessment roll of each such municipality for the current fiscal year. The board of directors shall determine the amount necessary to be raised by taxation, and shall apportion such amount among the several municipalities constituting the district according to the ratio which the value of all property assessed in each municipality bears to the total value of all property assessed in all such municipalities and shall fix a rate of tax to be levied which raise the amount of money required by the district. The commissioners shall thereupon, and within a reasonable time previous to the time when such municipality is required by law governing such municipality to fix its tax rate, certify to the taxing body of each municipality the rate so fixed with a direction that at the time and in the manner required by law for the levying of taxes for municipal purposes, such municipality shall levy and collect a tax, in addition to such other tax as may be levied by such municipality at the rate so fixed and determined, and it is made the duty of the officer or body having authority to levy taxes within such municipalities to levy the tax so required. And it shall be the duty of all municipal officers charged with the duty of collecting taxes, to collect such tax in time, form and manner as municipal taxes are collected, and when collected, to pay the same to the district ordering its levy and collection. Such tax shall be a lien upon all property within the municipalities comprising the district and of the same force and effect as other liens for taxes, and its collection may be enforced by the same means as provided for the enforcement of liens for State and municipal taxes.

Exclusion of Municipality

Sec. 28. Any municipality which may have become a part of said water district, as hereinbefore provided, may be excluded therefrom upon request of a majority of the electors of said municipality expressed in a special election called for that purpose by the legislative body of said municipality in accordance with the provisions herein, so far as the same are applicable for the holding of special elections; provided that if any objection is made to said exclusion by an ordinance of the legislative body of any of the other municipalities comprising such district, which said ordinance if it is passed must be passed within ten days after receiving from the legislative body of the municipality proposing to withdraw from the water district a certified copy of resolution or ordinance of intention to withdraw, then the commissioners of said district shall call a special election, as hereinbefore provided, for the purpose of submitting to the electors of the various municipalities the question whether such municipality may be excluded from said district. The commissioners shall ascertain the result of said election as certified by the proper officer or body of each of the municipalities comprising said district and voting thereat, and if a majority of all votes cast in the district shall be in favor of the exclusion of said municipality they shall certify the same and enter the result upon the minutes of the commissioners and from and after the date of such entry such municipality shall be excluded from the district, but such exclusion shall not operate to release it from any liability for the payment of any bonded debt incurred while it was a part of such district.

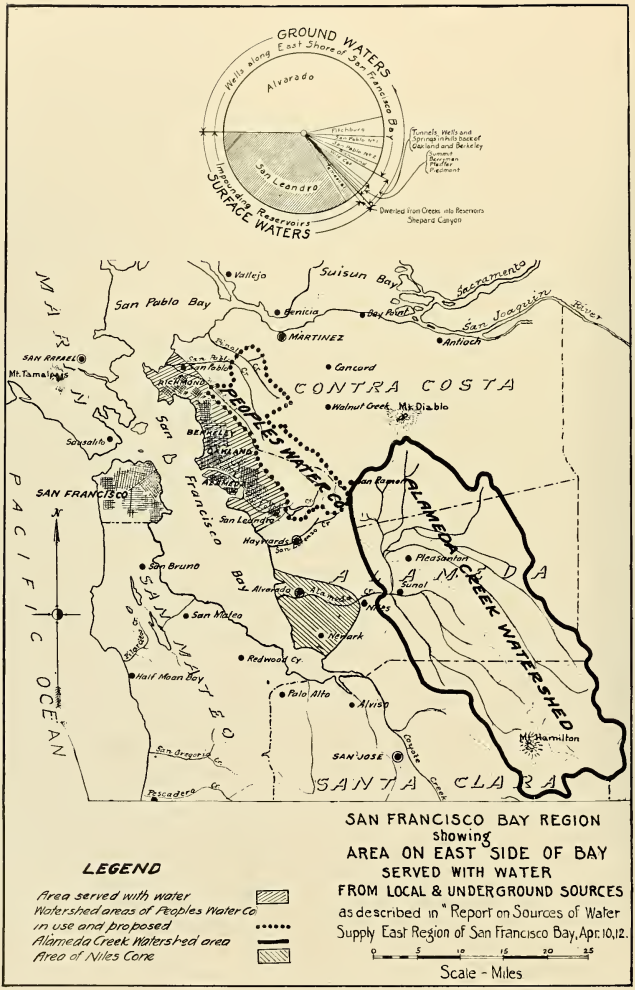
Inclusion of Municipality

Sec. 29. Whenever a petition is presented to the commissioners from any municipality asking that said municipality be made a part of said district and become subject to the privileges and provisions of this act, said commissioners may, in their discretion, pass a resolution authorizing the inclusion of said municipality, notice of which shall be mailed to the proper officer of each of the municipalities included in the district and if no objection is made thereto by the legislative body of any municipality then comprising said district within thirty days after the receipt of such notice, then the legislative body of said municipality so petitioning to be included in said district shall call a special election as provided herein for the purpose of submitting to the electors of said municipality the question whether or not said municipality shall join and become a part of said district. If a majority of the votes cast at the election shall be in favor of the municipality joining and becoming a part of said district the same shall be certified to the commissioners of the district, who in turn shall certify the same to the Secretary of State and thereafter said municipality shall be a part of said district and entitled to all the privileges and subject to all the obligations of this act.

Meaning of Certain Words

Sec. 30. Nothing in this act shall be construed as repealing or in anywise modifying the provisions of any other act relating to water or the supply of water to, or the acquisition thereof by municipalities within this State. The term "municipality" as used in this act shall include a consolidated city and county, city or town, and the word "district" shall apply, unless otherwise expressed or used, to a water district formed under the provisions of this act, and the word "board" and the words "board of directors" shall apply to the board of directors of such district, and the word "commissioners" shall apply to the commissioners of such water district, and the commissioners shall be regarded as a board of commissioners.

Sec. 31. This act shall take effect from and after its passage and approval.



SAN FRANCISCO BAY REGION
showing
AREA ON EAST SIDE OF BAY
SERVED WITH WATER
FROM LOCAL & UNDERGROUND SOURCES
as described in "Report on Sources of Water
Supply East Region of San Francisco Bay, Apr. 10, 12.

Appendix No. 3

THE PRESENT SOURCES SUPPLYING OAKLAND, BERKELEY, ALAMEDA, ETC.

The following is a summary of report filed with the Advisory Board of Army Engineers on July 15, 1912, on behalf of cities of Oakland, Berkeley et al., in relation to the Hetch Hetchy water supply:

The "Report on the Sources of Water Supply, East Region of San Francisco Bay," by J. H. Dockweiler, Consulting Engineer, dated April 10, 1912, treats of the properties of the various water companies, in detail; the quantity of water supplied from each of the different units; the capacities of the structures and the methods of operation, etc.

The proposed sources of water supply are also described and their capacities estimated; their availability from an economic and legal point of view is also touched upon.

An estimate is made of the probable future population of the region, with a statement of conditions surrounding the bay region, justifying expectation of rapid growth in the future.

The report comprises 509 numbered pages, in addition to a table of contents and 44 pages of minute index.

The first 140 pages contain the descriptive matter and text, and include 13 maps, 9 diagrams and 19 tables. The next 36 pages give the penetration records or logs of 96 wells, all of which are in platted form, and the last 333 pages contain the detailed information of the 3,841 wells which were visited and reported on by canvassers in the field, between August 14 and October 15, 1911. A map showing the location of each well accompanies the report.

General Statements and Conclusions

The east bay region described extends along the east shore of San Francisco Bay, from Richmond on the north to Alvarado on the south—a strip about thirty miles long, averaging five miles wide.

Immediately to the east, and extending northerly and southerly, is a range of hills, containing the several watershed areas which are the sources of the only available local water supply—surface and underground—for the use of the communities in this region. The underground gravels (considering the present development, surface and sub-surface) furnish the greater supply, but these gravel beds or cones depend for replenishment on the seepage from the flow of the streams fed by the above watersheds. In other words, *the limit of available draft on these cones depends directly on the amount of replenishment they receive by seepage from the creeks flowing onto them from the watershed areas.* The quantity received from the rainfall on the surface areas of the cones is comparatively small.

There are no municipally owned water plants in the east region of San Francisco Bay.

The People's Water Company plant, which supplies 97 per cent of the present consumption, *is being taxed to its utmost to meet demands.*

The cities of Oakland and Berkeley, the largest communities of the east bay region (realizing the necessity for a larger and additional water supply to meet the demands of the future growth on their side of the bay) desire to join with San Francisco in the proposed Hetch Hetchy source of water supply.

Demand and Supply From Present Sources

The larger cities included in this area are Oakland, Berkeley, Alameda and Richmond, which, together with the smaller towns and their environs, had a total population of about 235,000 two years ago, according to the United States census of 1910, and have since been growing rapidly.

	Mil. gals. daily.	Mil. gals. daily.
Total estimated capacity during a series of dry years—such as were experienced, beginning with the season 1897-98—of all available near-by sources, existing and proposed, for the east bay region		52.5
Surface Sources:		
Storage reservoirs	29.0	
Ground Water Sources:		
Niles Cone	8.5	
San Lorenzo, San Leandro and San Pablo cones	15.0	
The present consumption from all sources of supply approximates		26.9

The subdivisions of this total are given below.

Based upon estimated probable growth of population and increase in per capita consumption of water, the maximum safe capacity to which all available near-by sources could be developed by additional works will be reached by the year 1926. This date disregards certain legal obstacles discussed later.

Consumption of water, year 1910, east bay region, was as follows:

	Mil. gals. daily.	Mil. gals. daily.
Taken from surface sources and impounded in storage reservoirs of People's Water Co.		10.3
Taken from underground sources:		
By wells, tunnels, etc., of People's Water Co.	9.17	
By San Lorenzo Water Co.	.50	
By Hercules Water Co. to Pinole	.13	
By West San Pablo L. & W. Co.	.40	
By 3,841 wells, private source of water supply	6.40	
Total	16.60	16.6
Total for east bay region		26.9

Per capita consumption at present east side of bay:

From water companies	84
From private wells	30
Total per capita	114

Present Sources of Water Supply

The east bay region is supplied through the medium of four privately owned water companies, to-wit: The People's Water Company, which supplied 97 per cent of the water during the year 1910; The Union Water Company, The San Lorenzo Water Company, and the Hercules Water Company. These four companies, together with water extracted from 4,000 wells serving as sources of private water supply, constitute the water supply of the east bay region, extending from Hayward on the south to Richmond on the north, with a population of about 235,000, according to the census of 1910.

The sources of supply are divided into two classes: Surface water supply gathered in storage reservoirs from the water flowing off the surface during and after rainfall; ground water supply, furnished from wells located at the shore of the bay of San Francisco.

The surface supply consists of four storage reservoirs—Lake Chabot, Lake Temescal, and Piedmont Reservoirs No. 1 and No. 2. Total storage capacity of 5,000 million gallons, with a safe daily average delivery of about 8½ million gallons.

The ground water supply comprises in the main eight pumping stations located at different points, between Alvarado Wells in the Niles Cone on the south, and San Pablo Wells No. 2 in the San Pablo Cone on the north, with the remaining wells at points between in the stretch of thirty miles, along which these pumping stations are found, in addition to the motor power on about 4,000 private wells—present draft about 19 million gallons daily.

Proposed Extension of Supply From Near-by Sources

For additional near-by sources of water supply two systems have been proposed—surface waters to be caught in impounding reservoirs, and ground waters to be secured through wells.

The project of the People's Water Company for additional supply, by developing near-by sources, contemplates the utilization of the available surface sources of supply, and is treated of herein on a later page.

Underground Sources of Water Supply

The underground waters of the east side of San Francisco Bay are obtained from the territory at and adjoining the margin of the bay, and from the several cones or deltas lying in the plains between the bay and the mouths of the creeks that formed them.

Beginning at the south end of the bay the four principal cones are located as follows:

The southerly, and largest of all, is the Niles Cone, at the south end and easterly side of the bay; going north, this cone merges into the San Lorenzo Cone, which, in turn, joins the San Leandro Cone further north. No delta or cone formation then appears until the San Pablo Cone is encountered at the mouth of San Pablo and Wild Cat Creeks. The San Pablo Cone is supplied with water from the flow of Wild Cat and San Pablo Creeks. The other three cones are supplied through the watersheds of the creeks for which named.

Although no cone or delta formation is evident between Melrose on the south—assumed as the northern edge of the San Leandro Cone—and a point some miles north of Berkeley—assumed to be the southern edge of the San Pablo Cone—2,281 private wells have been bored in this area, producing about 4¼ million gallons of water daily. Included in this total are 362 wells in the city of Alameda, producing 1.1 million gallons daily. Hundreds of wells have been driven into each of the cones.

The areas of the watersheds tributary to the above mentioned cones are as follows:

Niles Cone, about	640 square miles.
San Lorenzo Cone, about	46 " "
San Leandro Cone, about	45 " "
San Pablo, about	35 " "

Including in the above areas of the three last mentioned cones the area of the foothills fronting the plain of the east shore of San Francisco Bay between Niles and Melrose, and adjoining San Lorenzo and San Leandro watersheds, which equals 25 square miles (some of the area between Niles and Haywards is tributary to Niles Cone), a total of about 150 square miles of drainage area is tributary to the three cones of the east bay region, lying north of the Niles Cone.

ADDITIONAL WATER SUPPLY FROM UNDERGROUND SOURCES.

Probable Legal Difficulties

In the light of recent decisions by the Supreme Court of California, quoted in Appendix No. 6, it is believed by the writer that no additional waters from underground sources can be appropriated for use upon any areas save those areas from which water is extracted, or upon areas in the immediate vicinity of the territory from which the water is so taken. In other words, it is believed that no waters can be diverted from one cone for use upon another cone if the requirements of the cone from which the water is being extracted demand said water.

It is assumed in the case of all underground waters now being diverted from any cone to localities outside of such cone, that title thereto vests in the parties who have so diverted water. But in view of the attitude of the people of the Niles Cone, who have recently served formal notice upon all water companies operating or about to operate in the Niles Cone region, to the effect that any additional diversion of water would be contested in the courts, the question of securing additional waters is one which may, and probably will, require the attention of the courts. Litigation is slow; demand for water is urgent.

The Niles Cone Water Needed at Home

The Niles Cone is the most prolific of all sources of underground supply of the east side of the bay. It is now being drawn upon for 14 million gallons daily, of which 8½ million gallons daily are being diverted for uses outside of the cone; about 8 million gallons daily being sent to Oakland, and ½ million gallons daily to the town of Haywards.

This cone has been suggested as a source of water supply toward furnishing additional water for the communities of the east bay region, located outside and north of the Niles Cone limits, and which number about 230,000 persons.

It is shown in the "Report on Water Supply of the Niles Cone Region," by J. H. Dockweiler, July 27, 1912, that to satisfy the ultimate local needs of the Niles Cone region, will require 56.7 million gallons daily. That Alameda Creek is the source of water supply for the Niles Cone gravels; that these gravels receive the Alameda Creek waters through percolation; that the total annual discharge of Alameda Creek, from its 623 square miles of watershed, during the six critical consecutive years of light rainfall, beginning with the year 1898, was 56 million gallons daily—the minimum year, 1898, being only 10 million gallons daily; that the Spring Valley Water Company diverted 15.6 million gallons daily to San Francisco during the year 1911; and that it proposes to divert additional water which is now urgently required by San Francisco, from Alameda Creek, thus reducing still further the quantity of water available for the replenishment of the Niles Cone; and, further, that it is not probable that any large amount of additional water will be allowed to be drawn from the Niles Cone for the use of these outside communities.

More Surface Storage Will Lessen the Ground Water Supply

The result of the lowering of the water table in the Niles Cone by the diversion to San Francisco of the waters of Alameda Creek (especially of the summer flow of Alameda Creek, and which creek replenishes the above water table) emphasizes the fact that the additional impounding reservoirs proposed by the People's Water Company, which reservoirs during critical rainfall periods would impound all waters now annually going to waste from their respective tributary watersheds, and thereby prevent the annual replenishment of the various cones—the San Leandro delta cone, the Hayward Cone and the San Pablo Cone—similar to the Niles Cone; hence the ground water level in the pervious gravel of these cones will gradually lower, reducing the volume of water available. In none of these three cones is there any large water storage capacity above mean sea level, and experience with ground water supply at the seashore the world over proves that for no extended period of time can the average ground water level of the ground water be dropped below mean sea level without becoming salty and unfit for domestic use and for use in steam boilers.

Project for Additional Supply by Developing Near-by Sources of People's Water Company

The Contra Costa Water Company (now the People's Water Company) made an investigation, beginning April, 1906, for the purpose of increasing the water supply of the east bay region. This work was done under the direction of Arthur L. Adams, Member A. S. C. E., and in his report, submitted March 12, 1908, to the People's Water Company, he concludes that 21 million gallons daily could be added to the capacity of the system by the construction of three additional impounding reservoirs in the creeks in the range of hills east of Oakland and Berkeley, and adjoining towns. These proposed reservoir sites are practically contiguous to the built-up sections —being on the other side of the hill crests—and with the rapid growth of population certain in time to have their watersheds built upon.

The three reservoirs proposed—on San Pablo, Pinole and San Leandro Creeks—would bring the total water supply from surface catchment areas up to 29½ million gallons. There are cones or delta-like formations at the mouths of San Leandro and San Pablo Creeks, and also San Lorenzo Creek, from which latter creeks' watersheds it is proposed to divert water into the proposed San Leandro reservoir.

Probable Opposition to Surface Storage Diversion

Because of an aroused adverse public opinion fortified by the recent court decisions quoted in Appendix No. 5, it is doubtful whether the proposed reservoirs on San Pablo and Pinole Creeks, contemplated by the People's Water Company, when built would be allowed to store and divert the waters which now supply the gravels at the mouths of said creeks—and from which creeks the annual replenishment comes to said gravels. Many wells are bored on the deltas of said creeks. The impounding of the water for the proposed reservoirs would lower the ground water in the cones. With the present draft maintained upon said wells in the cones, the ground water is certain to fall below mean sea level, resulting in the sea water ultimately entering and spoiling the wells. The wells of the Standard Oil Company and of the Santa Fe Railroad on the San Pablo Cone, are in ownership which promises a legal fight, backed with unlimited capital, if the output or quality of their water be interfered with.

Industrial Use of Ground Waters

On broad public grounds it appears best to leave these local waters available for industrial uses which properly can be less critical of quality than is necessary for a water used for drinking purposes. These cheap local ground waters will be helpful to the establishment of many branches of industry.

Example of the San Pablo Cone

The San Pablo delta cone presents an instructive example of local use outrunning to natural supply. No reservoirs have been built within the watersheds from which the cone is supplied, the run-off of the rainfall flows down the creeks toward the bay. Many wells have been sunk in this cone, which have caused a gradual lowering of the water plane, and in one particular instance the output of wells has decreased 70 per cent. San Pablo Wells No. 2, comprising a group of nine wells bored in 1907, with two additional ones in 1910 or 1911, produced but 590,000 gallons, daily average, for the year 1911, which is only 30 per cent of the amount given in a test of these same wells in 1907, which then showed a yield of two million gallons daily.

The Present Supply Furnished by The People's Water Company, Oakland

Practically all the water delivered to the communities in the east region of San Francisco Bay by public service corporations, is supplied by the People's Water Company.

The communities served comprise the cities of Oakland, Berkeley, Richmond, Piedmont, and the towns of San Leandro, Emeryville, Albany and Alvarado.

The People's Water Company supply is obtained from thirteen different sources and may be divided into two main groups, the surface sources and the ground water sources.

There has been a marked increase in the consumption of water in the communities supplied since the year 1902, as shown by the following table:

AVERAGE QUANTITY OF WATER USED FROM ALL SOURCES, MILLION GALLONS DAILY.

	Surface water.	Ground water.	Total
1902	7,913,925	4,907,275	12,821,200
1903	8,185,811	4,937,972	13,123,783
1904	8,847,483	5,104,099	13,951,582
1905	9,473,711	5,520,366	14,994,077
1906	10,677,282	5,619,061	16,296,343
1907	10,681,688	7,778,890	18,460,578
1908	10,317,417	8,977,250	19,294,667
1909	9,948,501	9,245,712	19,194,213
1910	10,286,686	9,171,001	19,457,687
1911	6,382,914	10,925,207	17,308,121

Effect of Complete Metering

It will be noted that in 1911 the average consumption dropped to 17,308,121 million gallons daily from 19,457,687 in 1910. This was due to the installation of meters in the Oakland division, which became 97 per cent metered.

A graphic representation of the average quantity of water furnished daily from the two classes of sources, and from each source in each class—surface and ground waters—of People's Water Company to east bay region during year 1911, follows.

See diagram at top of page 172 for graphic representation of average quantity of water—17,306,834 gallons—daily furnished from each source of supply of People's Water Company to east bay region during year 1911.

Present Yield of Each of the Several Sources

WATERS.

	Gallons.	Gallons.	Gallons.
Surface waters	—	—	6,381,626
Impounding reservoirs	—	6,302,484	
San Leandro reservoir	5,896,567		
Temescal	405,917		
Diverted from creeks into reservoir	—	79,142	
Shepard Canyon	79,142		
Ground waters	—	—	10,925,208
Wells along the east shore of San Francisco Bay	—	10,021,353	
Alvarado wells	8,051,416		
Fitchburg wells	746,429		
San Pablo wells No. 1	318,331		
San Pablo wells No. 2	590,006		
Richmond	315,171		
Tunnels, wells and springs in hills back of Oakland and Berkeley	—	903,855	
Wildcat wells and tunnels	471,373		
Summit Tunnel	145,506		
Berryman Tunnel	101,870		
Pfieffer Springs	55,086		
Piedmont Springs	130,020		
Grand total	—	—	17,306,834

Statistical Data, People's Water Company

The area served by the People's Water Company covers 67 square miles, divided into sixteen water service areas or pressure zones, and located between sea level and 1,000 feet above. Over 40 square miles are located below 200 feet elevation.

Two filtering stations, both containing mechanical filters, treat 99 per cent of the surface water. The underground waters are not filtered.

The system contains seventeen reservoirs, four with a combined capacity of 5,011 million gallons, are storage or impounding reservoirs, being sources of supply, of which Lake Chabot, formed by damming San Leandro Creek, is chief; thirteen are distributing reservoirs, with a combined capacity of 239,678,000 gallons, ranging from 28,000 gallons to 158,000,000 gallons capacity. These reservoirs are located at elevations varying from 80 feet above sea level to 950 feet.

There are eleven pumping stations, divided into two classes, one, those which deliver direct from a source; the other, those which re-pump, serving as "Boosters." There are five of the former and six of the latter. The total pump capacity is 52.1 million gallons daily, 16.5 at the source of supply, and 35.6 in boosters. During 1911 the former pumped 10 million gallons daily, and the latter 18.2, a total daily average of 28.2 million gallons, of which 14 million gallons daily were pumped once, 8.8 twice, 5.0 three times, and 0.4 four times.

There are 847.9 miles of pipe, of which 47 per cent is 2-inch and under, 50 per cent being 4-inch and under. Thirty per cent is cast iron, 3 by 16 inches; 10 per cent is sheet steel and iron, in size 4-inch to $37\frac{1}{2}$-inch; 50 per cent, standard screw, $\frac{1}{2}$-inch to 8-inch, and the remainder comprising casing, tubing, cement lined and converse.

The pipe system is a consolidation of ten water companies which have entered the field during the past forty-three years.

The number of active services, or taps, was 54,931 on January 1, 1912; pro-rating taps to date of 1910 census gives 4.58 persons per tap.

There were 52,392 meters installed at January 1, 1912, or a ratio of 95.4 per cent of all taps metered.

The People's Water Company, as well as all the other water companies (except mutual water companies, owned and operated by the stockholders themselves for private use) has its water rates established annually by the municipal or other governing body of the community which it serves. During the year 1911 its receipts per 1,000 gallons were 25 cents; expenses 11 cents. Gross receipts were $1,593,316; expenses, $698,494.

VARIOUS OTHER WATER COMPANIES SUPPLYING COMMUNITIES ON THE EAST SIDE OF SAN FRANCISCO BAY.

Union Water Company

The Union Water Company, a privately owned corporation, has entered the east bay region, proposing to supply water therein between Newark on the south, and Richmond, on the north. It has secured 20,000 contracts to supply consumers, of which it now serves 2,000.

Its sources of water supply are wells along the east shore of San Francisco Bay, having bored 103 up to March 15, 1912. These wells are located on the four cones or deltas, 12 being on the San Pablo Cone, 65 on the San Leandro Cone, 5 on the San Lorenzo Cone, and 14 on the Niles Cone, with the remaining 7 placed in three localities, presumably outside of the cones. From tests made of these 103 wells, the company claims a probable output of 16 million gallons daily. It now furnishes $\frac{1}{2}$ million gallons daily, from eight pumping plants located at various points between Newark and the town of Pullman, near Richmond.

It has two sections of its distribution system built, one in the town of San Leandro and the adjoining portion of Oakland, known as Elmhurst, with 54.6 miles of pipe; the other in the town of Pullman and vicinity, mileage 5.1 miles, or a total of 59.7 miles. Arranged by sizes, 35 per cent is 2-inch and under, 42 per cent being 4-inch and under. Twenty per cent of its pipes are cast iron, 4 to 10-inch, the remainder being steel screw, ¾ to 12-inch diameter.

It has 2,000 service connections, all metered, and the pumps deliver into the mains direct, automatic electric devices regulating the pressure.

San Lorenzo Water Company

The San Lorenzo Water Company supplies the town of Hayward with water, by means of wells located on a tract of 160 acres of land on the marsh, two miles southerly of Mt. Eden; pumping station being at west side of county road, leading from Mt. Eden to Alvarado, at edge of San Francisco Bay, upon an ear of the northerly edge of the Niles Cone. There are four 8-inch and 10-inch wells, varying from 400 to 500 feet in depth. Water is taken out of wells by means of an air lift, and the pumping plant—two Dow pumps—force the water to a reservoir—capacity 600,000 gallons—in Hayward, from which the distribution system leads off; the daily average quantity pumped being 500,000 gallons.

There are 1,279 service connections. The company reports that these wells have never been pumped to their capacity; that the surface of the water in them varies from ground surface to a few feet below, dependent upon the rate of pumping.

West San Pablo Land and Water Company

This supplies its entire output to the Standard Oil Company's works at Richmond. The sources of supply are sixteen wells, located along San Pablo Creek, between the town of San Pablo on the east and a point two miles west.

Depth of wells varies from 220 to 230 feet. Seven wells are equipped with deep well pumps, the remainder with air lifts.

Pumping station is about three-fourths mile west of Southern Pacific Company tract. This plant supplies, on an average, 400,000 gallons daily.

Hercules Water Company

The pumping station of the Hercules Water Company is situated west of Alvarado street in the town of San Pablo, on lots 179 and 183, San Pablo Rancho, between San Pablo and Wild Cat Creeks. The creeks here are about one-sixth of a mile apart. There are three wells, ranging from 181 to 335 feet in depth. In two of the wells the water is raised by air, one being equipped with a deep well pump.

The wells all discharge into a sump at an elevation of 50 feet above sea. From the sump an electrically driven double-action pump lifts the water to an elevation of 250 feet above sea, at which place the pipe runs over a hill, the water from here on flowing to Reservoir No. 2, situated northeast of the town of Pinole. The elevation of this reservoir is 100 feet above sea. Water from it is distributed to Pinole and Hercules.

The population supplied is about 1,100; number of services being about 225. No water is sold in the town of San Pablo, though there are a few consumers who tap the pipe line direct between the pumping station and the reservoir. The reservoir distributes about 130,000 gallons every twenty-four hours.

Appendix No. 4

THE DEPENDABLE ADDITIONAL WATER SUPPLY TO CITIES FROM ALAMEDA CREEK.

HOW SOON WILL WATER FROM THE TUOLUMNE RIVER BE NEEDED?

Estimate by JOHN R. FREEMAN, C. E., May, 1912.
(Revised to July 29, 1912.)

Among all of the undeveloped sources of water supply owned by the Spring Valley Water Company the only ones that I find of noteworthy importance for increasing the water supply to San Francisco are those of Alameda Creek lying upstream from the Niles Canyon. These comprise three reservoirs for storage of flood waters on Calaveras Creek, San Antonio Creek and the Arroyo Valle. Also a further development of the ground water supply by means of new lines of wells to be pumped, located farther up the valley than the present Pleasanton wells.

All of these can be made equally available to all of the cities around San Francisco Bay and can be used in connection with the aqueduct from the Tuolumne.

I have been requested by counsel for the city to set forth in an appendix the data and line of reasoning by which I reached the conclusions stated in the body of this report.

Diversity of Opinions

There is a great diversity of expert opinion about the additional quantity that can be derived from the Alameda-Sunol-Pleasanton-Livermore area, and it is of great importance to know the truth in order to estimate how soon San Francisco, Oakland, Berkeley, etc., will be driven to secure an additional supply from some more distant source, and also in order to value the water rights owned here by the Spring Valley Water Company.

The Dependable Yield of Alameda Creek

My own belief after studying all the information obtained from various sources is that the weight of evidence shows that although adverse water rights of the successors to the Bay Cities Water Company to 45 square miles of catchment at the head of Alameda Creek be disregarded and possible adverse rights of land owners of Niles Cone be also disregarded, and disregarding also the probable increase of local use in the Livermore Valley for irrigation by pumping, that not more than about 25 or 30 million gallons additional to what is already being drawn can be obtained *that can surely be depended upon* in a series of very dry years. If the above adverse claims were to be satisfied it is possible that no important amount could be taken in addition to what is now being drawn.

As to disregarding these adverse rights to the water from the 45 square miles of tributary catchment on the upper slopes of Mount Hamilton now owned by the Bay Cities Water Company or by the United Properties Company of Oakland, I am inclined to believe that the 10 or 15 million gallons more or less which might be gathered here by building dams and conduits will not be taken away because of the remoteness and the cost of conveying these waters to any point of sale; but I am strongly of the opinion that the possibilities of this 25 or 30 million gallons daily being lessened by local use in the Livermore and Pleasanton Valleys, and by adverse claims from the Niles Cone farmers, cannot be disregarded. This adverse use may develop slowly.

Taking all the conditions into account I am led to believe that construction work on the Hetch Hetchy source should be actively begun inside of five or ten years, that surveys and borings and road building should be begun this year or next and continuously carried on, and that probably the Calaveras reservoir and a new pipe across the head of San Francisco Bay should be pushed to earliest possible completion.

In other words, estimating with the conservation that is proper and common in planning the domestic water supply for great cities in a semi-arid land, one cannot properly reckon the total yield *available to the municipalities around San Francisco Bay* from all of the 623 square miles of catchment on Alameda Creek at more than 30 to 50 million gallons per day, of which about 15 million gallons daily is already being drawn, and *with strong probability that the additional quantity of say 25 or 30 million gallons daily now available from these sources will become smaller in future.*

The data and reasons which have led me to these conclusions are given in the following pages.

Averaging the sum total of every gallon that passed down through the Niles Canyon during the nineteen years from 1889 to 1908, as heretofore computed and published by the Spring Valley Water Company from its gauge records, including all diversion through its aqueduct to the city and plus the local supply furnished near outlet of canyon, plus all flood waste and plus all other flow past the Niles Canyon dams, day by day, *without correction or deduction of any kind*, this averaged only 132 million gallons per day, but it is plain there must be some very important corrections and deductions.

Uncertainties in the Spring Valley Record of Alameda Discharge

In the volume on California Hydrography published by the United States Geological Survey in 1903, Water Supply Paper 81, Mr. J. B. Lippincott, after calling attention to the errors and uncertain character of the measurements by the Spring Valley Company over its old dam in the Niles Canyon, corrects the record the best that he can and deduces during the 58 months of comparison a discharge averaging only . . . . 99 mil. gals. daily, against the Spring Valley's estimate for same period (still adhered to by Mr. Schussler) of . . . 141 mil. gals. daily, which discrepancy nearly all occurred during the flood months, and presumably the deduction was thought necessary because of the irregular shape of channel at dam, and the fact that its drowning by backwater in floods must very seriously decrease the discharge.

Mr. Williams reports that the Spring Valley computations were made by a formula proper for straight high weirs with clear overfall equivalent to $Q = 3.4\ L\ H^{3/2}$, with no deduction for backwater or the eddying cross-currents in the approach.

The above estimate by the U. S. Geological Survey reduces the Spring Valley's gross estimate by about $42/141 = 30$ per cent. This applies only to the ten years of gaugings up to 1899, inclusive.

Since the gaugings have been made over the new dam at Sunol the error is presumably much smaller, but this Sunol dam also has a badly obstructed get-away and is drowned out in floods, and much of the year's total discharge comes in floods and for this obstruction no allowance whatever has been made in the Spring Valley's estimates. We have no proof positive that Mr. Lippincott's adjustment is just right, but the shape of the river channel, photographs of the dam in flood and the formula used in computing the discharge, all make certain that the Schussler estimate exaggerates the real flow in the large floods. The fact that so much of the whole discharge for the year comes in these floods makes this error of measurement more important.

Reducing the Schussler estimate for his 19-year term by only 20 per cent would lessen his estimate by 26 million gallons daily, leaving 132—26=106 mil. gals. daily. instead of his 132.

There appears to be a good deal of uncertainty in the Spring Valley Company's record of heights over these dams, notwithstanding that it is a very simple matter to determine and record such matters with accuracy. Because of a mistake of computation in the Spring Valley office discovered by Mr. Williams, it appears the wrong placing of a decimal point had increased the record for March, 1898, from 575 million gallons to 5750 for the month, a deduction for this critically dry year of 5175 million gallons must be made equivalent to reducing the daily average 14.2 million gallons for the year 1897-8, or 0.73 million gallons daily for the term of 19 years.

Also there must be a small deduction because the records from 1889 to the latter part of 1900 included the run-off from 12 square miles between the Sunol and the Niles dams, which is no longer available for diversion to San Francisco, also about one-third of a million gallons daily (or more), which the company is said to be under obligations to deliver to riparian owners.

This average of 130.3 million gallons daily left in the Spring Valley record after correcting the decimal error above noted includes many flood torrents that it would have been utterly impracticable to store, and with the building of the three great storage reservoirs there comes unavoidable loss of somewhere between 6 and 10 million gallons per day from evaporation. And Mr. Williams further reports no allowance has been made for pump slip and piston rod displacement in the station records, which may have been 0.1 or 1.0 million gallons daily too large from this cause.

The Inaccurate Character of the Flood Gaugings

This supply comes mostly in floods. I am told that until recently there have been no accurate staffs set for measuring the depth at the so-called measuring weirs. The crest of the dams have been irregular and obstructed by planks or boards and most of the time the height was noted only once a day, even when varying rapidly after rains.

To show more plainly the impossibility of making any precise estimate of the flood flow over the Niles dam I present on the following pages a few recent photographs of the site, which will make the matter more plain to any experienced hydrographer than a written description.

The gravel bar at the southerly end of the Niles dam proves the existence of a strong eddy above the weir, induced by the sharp bend in the river shown a short distance upstream, which also keeps a hole scoured out in front of the north end of the dam. Plainly, in time of a great flood the current sets strongly against the north abutment from which the height was gaged, probably so much as to pile up the water here to an extent more than sufficient to compensate for velocity of approach, and this will apparently also be true in the extreme flood when head was measured from the manhole tower. The restricted channel just below the tower would seem to add to this tendency to pile up the water in floods at the place where its height was measured. This was probably worse formerly.

It is a general rule with regard to the flow over dams that disturbed eddying conditions will lessen discharge, and that a diagonal approach because of a bend or an eddy will also lessen the discharge as compared with an ideal weir, which the current approaches squarely.

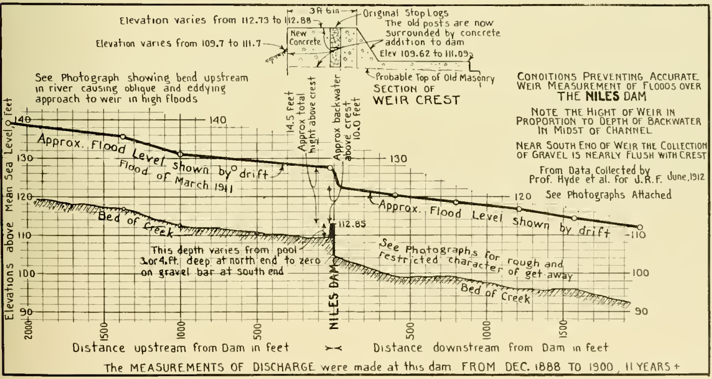
All of these disturbances absorb energy and thereby lessen the force which pushes the water over the weir, and it is difficult if not impossible to produce the same eddying effects on a small scale experimental model.

But the most instructive view of all for showing the absurdity of trying to accurately compute this flow at flood heights by formulas for an ideal weir with free discharge, is found in the profile along the bed of the stream, traced by the flood marks on the bushes and shores.

A profile of flood heights in the flood of 1911 thus traced is presented below and on the following page are presented photographs showing other unfavorable conditions for accurate measurement. Note the extreme drowning of the crest and consider the retarding effect that this must have had.

The case is all the worse when we consider that it is from the storage of floods measured in this grossly inaccurate manner that the claimed vast capabilities of Alameda Creek for the future supply of San Francisco have been estimated.

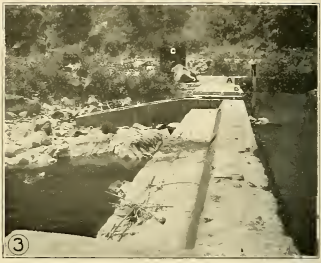
At the Sunol dam the photographs show an excellently straight channel of approach and for moderate depths the discharge measurement would be fairly accurate except for the irregular pieces of board commonly attached to the concrete crest, but at flood heights this weir also becomes so drowned that it is utterly worthless as an instrument for measurement and any attempt to compute discharge over it by formulas for an ideal weir having free fall must grossly exaggerate the quantity. Particular attention is called to the longitudinal profile over this weir in the flood of January 15, 1911.



FORMER CREST OF NILES DAM.

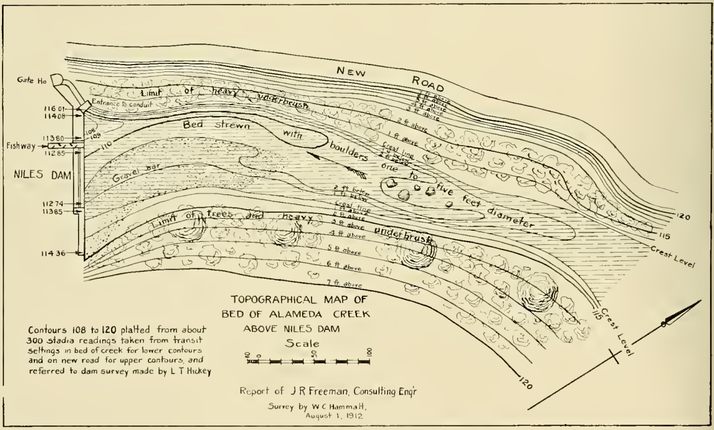
Note the badly obstructed get-away, and particularly note that the situation in time of flood would tend to an increase of height of water as measured on the manhole chimney on which man is standing more than enough to compensate for effect of "velocity of approach."

Note obstruction by fishway. The get-away for water around the chimney probably is now more open than formerly because of building road. Compare with (3).



NILES DAM CREST, AS REPAIRED WITH CONCRETE.

The water height in floods was measured on chimney C. In small floods was measured down from corner of A. In low-water measurement was taken below corner B, against the upstream face, all apparently tending to automatically correct for velocity of approach.



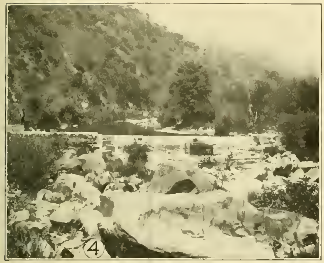
TOPOGRAPHICAL MAP OF
BED OF ALAMEDA CREEK
ABOVE NILES DAM

Contours 108 to 120 platted from about 300 stadia readings taken from transit settings in bed of creek for lower contours and on new road for upper contours, and referred to dam survey made by L T Hickey

Report of J R Freeman, Consulting Engr

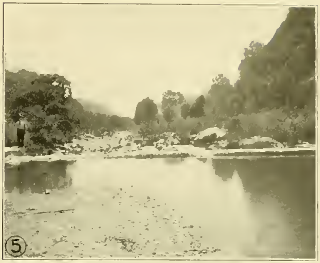
Survey by W C Hammatt,
August 1, 1912

CONDITIONS MAKING ACCURATE MEASUREMENT IMPOSSIBLE



NILES DAM. S. V. W. CO.—GENERAL VIEW, LOOKING UPSTREAM.

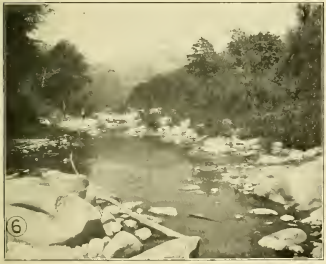
Note the bend in the river upstream which causes the current to approach the weir diagonally and tends to pile up the water at the end where the height was measured.



LOOKING DOWNSTREAM OVER NILES DAM.

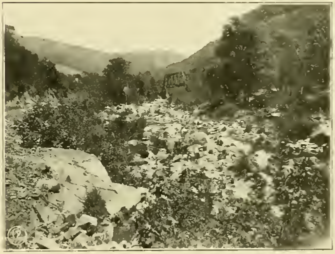
Note the gravel bar deposited by the eddy just upstream from southerly end of dam, nearly flush with crest.

Note the abrasion of south end of crest in (3) above, due to cobbles and gravel rolled over by flood after being rolled along face up the incline of the gravel bar by the diagonal current.



LOOKING UPSTREAM TOWARD NILES DAM FROM BELOW.

Showing obstructed channel.



THE CHANNEL OF ALAMEDA CREEK DOWNSTREAM FROM SUNOL DAM, AND UPSTREAM FROM NILES DAM.

Showing obstruction by rough bed and bushes, which cause the backwater.

THE SUNOL DAM IN FLOOD.
(Probably January 15, 1911, about 10:30 A. M.)

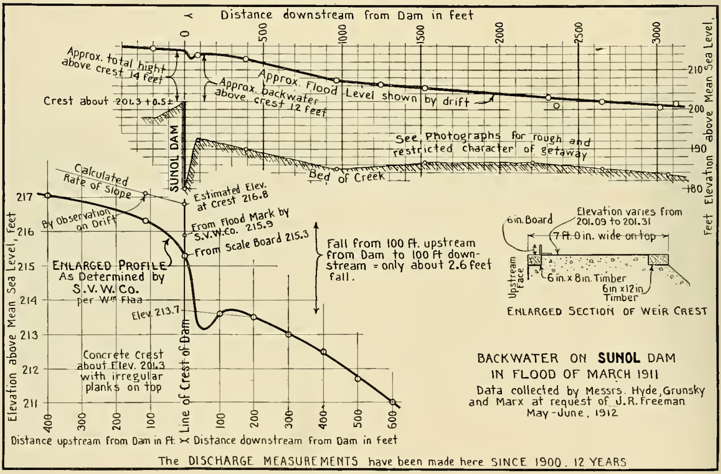
Showing the backwater in flood. Note from the shallow depth shown flowing over the east wing that serious backwater exists under less than the highest floods.

The above was a relatively small flood. The height on dam was about 4 feet 3 inches, or less than one-third that shown on the profile.

THE SUNOL DAM IN FLOOD.
(Probably January 15, 1911, about 10:30 A. M.)

These discharges said to have been computed by S. V. Co. as for an ideal weir with free discharge.

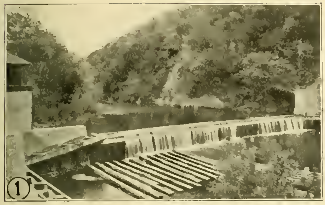
The marks indicate depth about 4 feet 1 inch above dam at time of photograph.



BACKWATER ON **SUNOL** DAM
IN FLOOD OF MARCH 1911
Data collected by Messrs. Hyde, Grunsky and Marx at request of J. R. Freeman
May-June, 1912

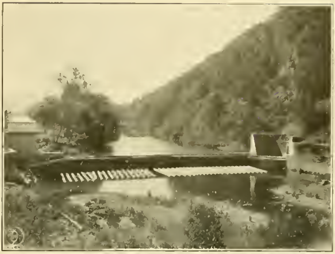
The DISCHARGE MEASUREMENTS have been made here SINCE 1900. 12 YEARS

SPRING VALLEY GAUGING WEIR AT SUNOL DAM



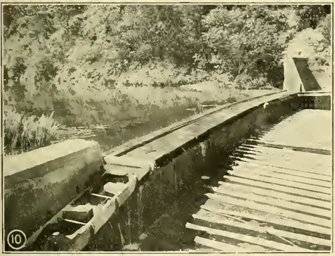
FROM NEARLY SAME VIEWPOINT AS FLOOD PICTURE OPPOSITE.

Note the irregular level of crestboard.



THE SUNOL DAM, LOOKING UPSTREAM.

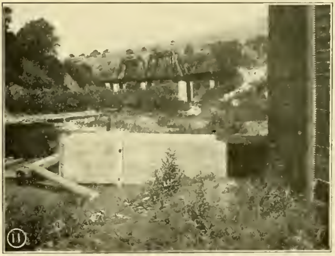
Note the excellent straight approach.



SUNOL DAM, WITH CREST DRY.

Note the obstruction of fishway and the irregular flashboard on top of crest.

(The raft below floats, and is for lessening erosion.)



THE NEW GAUGE STAFFS AT THE SUNOL DAM.

Note that position avoids need of correcting for velocity of approach for moderate depths. The strong current at time of flood tends to pile up the water against these gauges.

Differences in Estimates by Different Experts

In his affidavit of June 20, 1908, as filed in the U. S. circuit court, prior to large recent purchases of water-bearing land at Pleasanton and the adjustment of restrictive litigation, Mr. Schussler estimated the yield available to the city at...........90 mil. gals. daily.

In November, 1911, since large additional purchases of artesian land near Pleasanton and the consequent release from certain adverse claims, he reckoned the total supply available to the city from the Alameda sources at........................119 mil. gals. daily.

Mr. Cyril Williams, Jr., from a most thorough and painstaking study, occupying nearly a full year of his time, a full report of which is to be filed with the Board of Army Engineers August 1, and of which a copy has been given the Spring Valley Company in exchange for copies of certain of their own estimates, reckons it at......................50 mil. gals. daily.

The present rate of draft for the whole year 1911 averaged........................15.6 mil. gals. daily.

(The Pleasanton wells pump is commonly shut down part of the year. The Sunol filters deliver continuously.)

And none of the above estimates by Mr. Schussler or Mr. Williams take account of the possible adverse use of the water rights claimed to be owned by the Bay Cities Water Company, which cover about 45 square miles of the most prolific part of this catchment area, and from which Mr. Edwin T. Duryea, Jr., C. E., estimates after 3 to 5 years of very complete gaugings of rainfall and runoff that his clients can possibly divert about 20 million gallons daily. A study of the Relief Map near the beginning of this report is very suggestive as to the proportionate yield of these 45 square miles, a part of which is comprised in the high seaward face of Mt. Hamilton.

Nor do they allow for the fact that some time there may come a longer series of dry years in succession than has occurred since 1889.

Nor do they allow for the possible adverse rights of those living within the area of the Niles Cone to the percolating waters they have heretofore enjoyed, which they would lose in large part if the ground water table were lowered as it surely would be by not permitting any water whatever to flow down the bed of the stream through the Niles Canyon during the long period of nineteen years.

The Yield Above Pleasanton

A recent joint report by William Mulholland and J. B. Lippincott (engineers of the Los Angeles Aqueduct), dated February 7, 1912, made at the request of the Spring Valley Water Company, presented no estimate on the total yield of the Alameda sources or upon the separate yield from this region tributary to the proposed Calaveras Creek. In this report they estimated that the 406 square miles (401 per C. W., Jr.) lying upstream from Livermore and Pleasanton can be made to yield..............51.5 mil. gals. daily

This excluded the yield of the 100 square miles of the Calaveras Creek, and excluded the 34.6 square miles of upper Alameda Creek, and also excluded the 38.7 square miles on San Antonio Creek, upstream from its proposed dam site, and excluded the yield of the Sunol Valley region, comprising 48.5 square miles. The total portion thus excluded from their estimates aggregated 221.8 square miles, which is well known to be the most prolific portion of the 623 square miles, *this excluded portion probably yielding as much as all the rest*, though its area is only about one-third.

Indeed, the few years of crude gaugings made by the Spring Valley Company showed that this Calaveras area not covered by the Lippincott and Mulholland estimate above quoted (less than one-fifth of the whole area) in dry years furnished more than three-quarters of the entire yield, and never less than half.

This estimate by Messrs. Mulholland and Lippincott covers a very little more area than that tributary to the Pleasanton region from which Mr. Schussler, in page 28 of his report of November 14, 1911, concluded that there could be derived.......46 mil. gals. daily.

Thus it will be seen that the Mulholland and Lippincott report does not differ widely from Mr. Schussler's. Both Mr. Schussler and Mr. Mulholland assume that the Arroyo Valle reservoir will be built and that its surface storage of about 12 billion gallons, when used in connection with the present natural subterranean storage would practically serve to conserve and regulate the *entire run-off* from the rainfall as found in this region *during the nineteen years* from 1889 to 1908, which I believe absolutely impossible for reasons given later.

Mr. Cyril Williams, Jr., by the painstaking and complete report, already referred to, comprising upward of 600 pages of text, with many elaborate statistical tables and diagrams, concludes that the entire amount derivable, with fullest reservoir development, from the

623 square miles above the Sunol dam will be in round numbers........................50 mil. gals. daily; and on studying the several reports by Schussler, Grunsky, Von Geldern, Storrow, Hering and others, it quickly becomes plain that Mr. Williams has collected vastly more data and studies them with far more thoroughness than any of the other investigators.

My own conclusions, after having carefully studied the several reports above mentioned and having personally visited this valley several times, and having studied all the data available to me upon rainfall, run-off and climatic conditions in this part of California, is that even Mr. Williams' estimate is a little too liberal, and that in striving to give to the Water Company the benefits of the margin of uncertainty and in estimating the greatest theoretic amount available rather than in all cases follow the general practical course of water works operation, and *by also omitting to take full account of the present and future local use of water,* he has arrived at a figure that may be considerably greater than the amount that could be surely depended upon for future diversion to the city, in a series of extremely dry years.

Practical Yield Smaller Than Maximum Theoretic

It is a fact in the operation of water works that the degree of conservation and storage technically or theoretically possible is not attained in practice, because of various business reasons. For example, in the Croton supply of the city of New York, the engineers familiar with the practical necessities of the case are substantially unanimous in the belief that the present development so as to give a dependable supply of about 325 million gallons daily, is as far as it will ever pay to go, notwithstanding there are times when vast quantities of water will run to waste over the Croton dam, and therefore the large new additional supply, whose construction works are now nearing completion, was sought in the Catskill Mountain region.

It is a matter of actual experience in the water supply of large cities that it does not pay (and also is impracticable) to carry the development of storage to a point beyond that which will conserve and permit the diversion of the entire flow during a period longer than the two, three, four or five driest consecutive years, and Boston, New York, Baltimore, and so far as I know, all other large cities dependent upon surface storage have sought new sources and considered their previous sources fully developed *while water still ran to waste from them during more than half of the years of a twenty or thirty-year period.* It is widely recognized among water supply experts that it is disadvantageous to hold storage reservoirs partially empty continuously over more than from two to five years in succession, because of the growths of weeds on the exposed beds, etc. Stearns, Fitzgerald and other experienced water supply engineers have emphasized this in various writings and have generally set the limit at three years.

The error in the large estimates by Schussler, Mulholland and others quoted above come chiefly from the fact that they practically assume that for twenty years at a time, not a gallon is to be allowed to escape by wastage over the Spring Valley Water Company's dam at Sunol; and I find that Mr. Cyril Williams, Jr., also is too thrifty in assuming that the surface reservoirs upon which he has to rely for conserving the flood waters will be so capacious that for ten consecutive years in the cycle of years of small rainfall the water will stand below the crest of the dam and not a gallon run to waste.

Local Use Will Lessen Supply Available to Cities

It appears to me, also, when looking at the situation in a broad, practical way, that each of the engineers quoted above has gone too far in neglecting the *possible large increase of local use* on the fertile lands of the Livermore Valley by pumping for irrigation under the probable future development of intensive farming with the stimulus of cheap electric power, and that there are possibilities of manufacturing use and municipal growth near Livermore and Pleasanton that will demand more water.

Then, too, the fact must be at least recognized, particularly when appraising the 100 square miles of the Calaveras Creek source, which supplies probably 40 per cent of all that comes from the 623 square miles above Sunol, that 45 square miles or *nearly half of what is by far the most prolific portion of this area* is subject to water priorities, claimed by the Bay Cities Water Company on Smith, Isabel, Valle and Bonito Creeks, which, if diverted, would take away perhaps 10 or 15 million gallons daily from the total of 50 million gallons daily found by Mr. Williams. The chief engineer of that company has recently stated to me that the company is still doing work to maintain its rights to divert this water. I have already expressed my belief that this probably will not be diverted because of remoteness and lack of profitable market.

Moreover, all of the foregoing estimates by Mr. Williams, Mr. Schussler et al., have tacitly assumed that for ten or twenty years at a time, *the diversion of every gallon* of the water which has heretofore flowed down the Niles Canyon at certain seasons of the year and has spread out and sunken into the porous subsoil of the large and fertile area known as the "Niles Cone," would be tolerated by the courts and by the Legislature, regardless of any legal or moral rights which the communities and the individual farmers may have acquired to the replenishment from Alameda Creek for the ground water so necessary to their continued prosperity.

If substantially every gallon of this outflow from the Niles Cone were held back and diverted for ten years at a time in the cycle of years of low rainfall, *it is certain that this diversion would make still more severe the shortage of water that residents of the cone would suffer*, and it is not improbable that court or Legislature would give them relief, regardless of the part that their own excessive local pumping might have had in producing the shortage.

A Rough and Ready, But Convincing Estimate

Anyone at all familiar with water supply matters can quickly figure out for himself the main facts in this situation, without need of going through the many pages of Mr. Williams' painstaking compilation and analysis of the records, except for greater precision.

The one bedrock fact on which is founded all of the various estimates of yield by Schussler, Mulholland, Grunsky, Williams and others, quoted above, is the *record of gagings made near the head of the Niles Canyon, by the Spring Valley Water Company;* which gagings made at the Niles Dam and the Sunol Dam, respectively, show at face value an average yearly discharge from these 623 square miles of catchment now under discussion for the nineteen years, 1889 to 1908, inclusive, averaging...........132 million gallons daily.

As already stated, this figure is too large because of a decimal error and also too large because of errors in computing the flood flow over a drowned weir as if it were an ideal weir with deep straight approach and free discharge.

The Wide Fluctuations of Discharge Make Complete Conservation Impracticable

The difference between the estimates by the various experts come chiefly from difference in opinion as to how much of this total flow in flood and drought for nineteen years it would have been practical to conserve and make available for delivery to San Francisco by means of storage in the proposed future three large surface reservoirs, Calaveras, Valle and San Antonio, in combination with the subterranean reservoir of *uncertain extent and uncertain availability* that is found in the vast gravel deposits near Sunol, Pleasanton and Livermore.

This entire region of 623 square miles area, but particularly the mountainous portion, is subject to most violent and wide fluctuations in streamflow, and the surface flow of all of these creeks ceases entirely at time of prolonged drought. Therefore, great storage is a fundamental necessity in all of this catchment area.

Following a heavy and widespread rainfall, fierce torrents pour down these tributary valleys, the streams rising to the full height in the course of a very few hours and shrinking with great rapidity after the rain has ceased, and *a large part of the entire year's runoff sometimes is delivered from a single storm.*

Beyond this there is wide fluctuation of the discharge in different years; for example, the Spring Valley records, presented on a following page, show over forty times as much total runoff in the year 1889-90 as in the year 1897-98.

The extent to which these wide fluctuations can be controlled and the finding out just how much of the large quantity that now runs to waste in these brief torrents, can be stored and held in storage, not only for days, but for long years, until needed, gives rise to problems which cannot be answered in a perfectly positive manner, with the very insufficient surveys, borings and flow measurements that have yet been accumulated.

Wherever serious doubt or uncertainty exists in data for estimating a source of additional supply for a city, *the doubt should be construed in favor of safety.* A factory can shut down without disaster when its water power goes dry and river boats can wait for a rise, but a city cannot risk the disaster that must follow any substantial shortage in its domestic water supply.

A rule of world-wide application in the development of municipal water supply is to *seldom or never go beyond what the records show can be depended on during the two or three consecutive years of smallest known discharge.* In some few cases where vast storage reservoirs are practicable, the total flow of a five-year period may be considered.

In California, and particularly at San Francisco, this principle of large storage has probably been carried farther than anywhere else in either America or Europe. The further extension of the Crystal Springs dam is proposed only in connection with the conservation of surplus waters to be brought from transbay regions.

Gaugings of Alameda Creek

The following table is that already referred to as the most instructive and important of all of the exhibits in relation to the yield of the Alameda region. The same data are understood to furnish the chief basis of the Williams, Mulholland and other studies.

DISCHARGE OF ALAMEDA CREEK, AS OBSERVED AND COMPUTED BY THE S. V. W. CO.

(Columns 1 and 2, 1889 to 1904 inclusive, are from Exhibit No. 7 in the case of Spring Valley Water Co. vs. City and County of San Francisco, testimony of Herman Schussler, U. S. Circuit Court, No. 13595, Vol. 1, see pages 170-175 of transcript. Filed in 1906.)

Seasons	Total Seasonal Runoff from Entire Alameda Watershed, Million Gallons	Equivalent Average, Million Gallons Daily	
1889-90	156,148	426.	Seasonal year taken as Nov. 1
1890-91	35,125	94.	to Oct. 31; until Oct. 30,
1891-92	19,051	52.	1903.
1892-93	102,676	279.	Subsequently to July 1, 1904, year
1893-94	55,155	151.	is taken July 1 to June 30, 1903-
1894-95	81,827	224.	04; record thus includes only 8
1895-96	37,232	102.	months.
1896-97	63,472	174.	
1897-98	8,787*	24.	Corrected gives only 10.
1898-99	24,849	68.	Corrected 2 yr. average 39.
1899-1900	18,158	50.	Corrected 3 yr. average 42.6
1900-01	32,102	88.	Corrected 4 yr. average 54.
1901-02	19,717	54.	For six consecutive years the cor-
1902-03	23,500	64.	rected average is 56.
1903-04	36,731	101.	
1904-05	20,254	56.	
1905-06	63,134	173.	
1906-07	102,917	278.	
1907-08	21,189	58.	
Total,	918,024 mil. gals.		(Corrected 912,849)

Annual average for 19 years, 48,317 million gallons. (Cor. 48,050.)

Equivalent average per day, 132.2 million gallons. (Cor. 131.5)

*In the year's record of 1897-8 a misplaced decimal point in the flow for March is reported to have caused an exaggeration of 14. million gallons daily in the daily average for this driest year. This has been corrected only in the figures at the right, and is seen to signify little in the final average, but means much in the critical period. The true total for that year instead of 8787 million gallons is 3612 million gallons.

Taking these figures at face value, it is of particular importance in this table to note that the total of every gallon coming from the 623 square miles in the year 1897-98 was only . . . . 10.1 mil. gals. daily, (which indicates the limited effect of the Livermore gravel storage as a natural regulator).

And for the average of that year and the following year, the total yield of the 623 square miles was only . . . . 39 mil. gals. daily.

And that for the three consecutive years, 97 - 98, 98 - 99, 99 - 1900, the average was only . . . . 42.6 mil. gals. daily.

And if not a single gallon had been permitted to waste down thru the canyon into Niles Cone during the six consecutive years, 1897-98 *to* 1902-03, *inclusive, the average quantity, without allowing for waste* by evaporation and seepage during the long storage, would have been *only* . . . . 56 mil. gals. daily.

If everything had been held back even for eight consecutive years, to 1904-05, the average would have been only. . . . 61.4 mil. gals. daily.

But this eight years would be a longer period of complete detention *than has ever been followed in practice*, so far as I am aware, and *probably longer than would be permitted here without effective protest from those living on the Niles Cone.*

These arithmetical average quantities recorded above, 38 to 56 million gallons daily, are much larger than could possibly be available under the artificial condition of regulation by storage, because the three great storage reservoirs which would have to be first constructed would present an average area of about 2200 acres, exposed to evaporation and the net loss from this surface in the warm, dry climate of Cailfornia, would average about six to ten million gallons per day.

Thus *for the six-year period*, which is the very longest that in my opinion we are justified in considering, *the total flow available for diversion to the city would be only* (assuming the correctness of Mr. Schussler's gaugings, disregarding for the moment correction for the drowned weir):

An average total natural runoff of. . 55 mil. gals. daily.
Less an average increase in evaporation loss, say. . . . . 8 mil. gals. daily.

Thus leaving as the total runoff from the 623 square miles only. . . . . . 47 mil. gals. daily.

The Quantity Gauged is Not All Available

And *even this 47 million gallons* is *subject to deduction* and allowances when planning a water supply for the long future, *because of the certainty*, that with the growth of industry and particularly with *the increase in intensive farming, stimulated by irrigation*, more and more of the rainfall which now soaks into the porous gravels near Livermore will be brought to the surface and largely evaporated in the process of irrigation and plant transpiration.

Moreover, if it were attempted to use the proposed storage reservoirs on Arroyo Valle for feeding the natural filter ground above Livermore and Pleasanton, there would in this process be some unavoidable loss by evaporation, and if an attempt is made to feed the natural filter grounds at Sunol from water stored in the proposed Calaveras and San Antonio reservoirs there will be some additional loss.

Beyond this there must be considered the questions as to whether the complete diversion of every gallon of flow from the Niles Canyon will be permitted by the farmers and other local users of ground water by pumping, and by the courts, for so long a period as six or eight years.

There is also the remote possibility of diminution by reason of the Union Water Company developing its *adverse water priorities to nearly half of the Calaveras catchment*, from which probably ten million gallons or more daily of the foregoing estimate is derived.

In the purchase of a mine or of anything where the element of value has dimly-defined boundaries, it is a general principle of business *to construe the doubt mainly in favor of the purchaser*, and it is invariably the rule of conservative engineers to *decide the doubtful points on the side of safety* when planning a domestic water supply.

Therefore, from the best of my present information and after having carefully reviewed the elaborate estimates of Mr. Williams and also the figures of Mr. Schussler, Mr. Lippincott, Mr. Mulholland, Mr. Von Geldern and others, I have come back to substantially the result already stated and conclude that from present information, both when valuing the possibilities of the Alameda supply for its purchase and complete development by the city, and also when considering the date at which the limits of this source will have been reached in supplying San Francisco and the other bay cities, so that the seeking of a new additional source of supply will be imperative, I am of the opinion that we must reckon everything in the 623 square miles tributary to Sunol as safe for *only* 30 *to* 40 *million gallons per day* that can be diverted to San Francisco of which 15 to 17 million gallons is now being taken daily, and that this surplus of 15 million or 20 million gallons daily, will gradually shrink under the development of intensive farming in the Livermore Valley, irrigated from pumped ground water, and may be reduced to almost nothing from adverse causes stated.

I believe it open to question if it will be prudent to rely on diverting more than can be had from storing flood waters in Calaveras reservoir, but am hopeful that gauging will show it advisable to also build the Antonio and Valle reservoirs.

Mr. Cyril Williams, Jr., has made all of the data and various elements of the problem so plain in his elaborate report, to be filed with the Army Board August 1st, and has discovered so much new data in rain gauge records, well borer's records, etc., etc., that I will not myself go over the same ground as Mr. Williams, except to say that accepting the data which he presents as correct (and I see no reason to doubt, but find much independent evidence to confirm it), I find myself in general agreement with most of his conclusions.

Instead of following his laborious method of analysis, which is on file and speaks for itself, I will follow an independent line of demonstration, trying to make the proof plain on commonsense grounds. But first, it may be of interest for me to very briefly state my views as to the reasons for the discrepancies between Mr. Williams' estimate and those of Mr. Schussler and Mr. Mulholland.

The Overworked Gravel Storage

I find that altho there are some small differences, because of differences in the rate of evaporation assumed from the surface of the great reservoirs, and some little differences in the distribution of the railfall assumed, the large discrepancies in the final estimate of yield *nearly all arise from the different views held as to the storage capacity available for use in the great gravel deposits upstream from Pleasanton and Livermore.*

Moreover, the Spring Valley Water Company has doubtless been misled into over-estimating the quantity of water which it could obtain from the proposed storage reservoir on Calaveras Creek by reason of some erroneous gauge records made by men in its employ, of the discharge of the creek during the years 1903 to 1908.

That an over-estimate of the regulating capacity of the gravel deposits upstream from Pleasanton has been made by Mr. Schussler and Mr. Mulholland is *plainly shown by the correlation of the borings which define the limits of these gravel deposits* in the several geologic sections, carefully made by Mr. Williams and about which extremely little detailed information is presented in the Schussler, Mulholland or Grunsky reports. Examples of these sections are given on a previous page.

That *these gravels cannot be utilized for future storage to any vastly greater extent than at present* can also be seen in a commonsense way by studying the yearly record of total runoff presented by Mr. Schussler, already referred to, and noting that in the torrential floods from these mountain valleys *the water comes down at a rate so fast that the gravels cannot drink it in*, and by noting that *the effect of a year of excessive rainfall is lost in the record of the following year.* These records plainly show that, notwithstanding this broad gravel basin is *tipped up* so that its inlet on Arroyo Valle Creek and Mocho Creek is from 200 to 300 feet higher than its outlet along Laguna Creek, the total runoff in the dry year 1897-98 *was less than one-seventeenth part of the runoff in the preceding wet year* 1896-97.

Similarly the total runoff in the year 1890-91 was about one-fifth part of the runoff in the year 1889-90, and the runoff in 1907-08 was only one-fifth part of the runoff in the preceding wet year 1906-07.

The gravels fail to drink in nearly all of the quick flood, following heavy rainstorms, and a little later the yield of the springs at the exit from the gravels rapidly fades away. (See page 87.)

This proves conclusively that under natural conditions these broad gravel beds exercise only small regulating influence.

The records of the borings presented in such excellent form by Mr. Williams also *apparently demonstrate beyond the shadow of a doubt* that it is absolutely impossible, by means of the utmost practical development of wells and pumps, to make these gravels play the part that Messrs. Mulholland and Lippincott have reckoned they can be made to perform. (See profiles on page 89.)

The Bearing of Geological Studies

In this connection, I have carefully studied the two reports of Prof. Branner (December 1, 1911, and May 6, 1912) as to the depth of the geological re-fill of this valley, and while I have not the slightest doubt as to the correctness of his general conclusions, it is, I believe, a matter of plain commonsense, in view of the records of the borings, that no vast underground reservoir exists *that can be made practically useful for largely augmenting the present supply.*

It is of particular interest to note that Prof. Branner describes the gravel deposits as non-continuous and that they lie in lenses and that he attempts no quantitative estimate of the water that could be derived from them in the practical way.

We must look to the skies and the running streams, not to the ground, for the water sources. No matter how vast the underground reservoir in porous gravels, *these can give out no more than they drink* in. Porous gravel too deep for practical drainage is useless for water supply. Gravel whose interstices are clogged with silt are useless for these practical purposes, and after all, the one measure of utmost possibility of yield is in the records of daily outflow in flood and drought, measured during nineteen (or twenty-three) years by the Spring Valley Company's engineers and already discussed.

If ever twenty million gallons daily is diverted through the Calaveras tunnel proposed by Mr. Schussler and ten million gallons, more or less, become similarly diverted from the Arroyo Valle reservoir, also proposed by him, the waters which feed the gravels and the filter gallery at Sunol and the waters which feed the gravels around the present wells at Pleasanton will be reduced by just this amount, and a limit will be found beyond which one cannot store water in the foothill valleys and divert it through the tunnels without producing shortage at the Pleasanton wells and Sunol galleries.

The sections on page 90 tell the story of underground storage more effectively than words.

Surface Reservoirs Here Promise Better Than That Underground

The increase in ground water hoped for above the present yearly average draft of 15 million gallons daily to a future 40 million gallons daily would have to be obtained almost solely from storage of flood waters in the three great reservoirs proposed on Calaveras, San Antonio and Valle Creeks. (At present the Pleasanton wells are pumped only a part of the year.)

I concur fully with Mr. Williams, after an independent study of my own as to rainfall, runoff and storage on the several tributaries, that after the Calaveras, Antonio and Valle Creeks have had their flood flows conserved by the proposed reservoirs and diverted in the most economical manner by means of tunnels and conduits between the several reservoirs and the cities, the amount which then can possibly enter the Livermore gravels from all the remaining tributaries *will be hardly more than enough in a dry time to maintain the present yield of the Pleasanton wells*, and that similarly the Sunol filter gallery will not have more than sufficient water tributary to it to keep up its present delivery.

I believe the reservoirs at Calaveras and Sunol should be developed in connection with the Tuolumne aqueduct, perhaps also the Arroyo Valle reservoir, largely for the purpose of safeguarding this or any distant supply and permitting plenty of time for repairs on aqueduct. But I am confident that it will never become advisable to develop any large permanent additional supply from wells in the Livermore Valley, though possibly 5 or 10 million gallons daily could be thus obtained by deep pumping.

From my experience, and particularly from my studies of similar problems on Long Island for the City of New York, I doubt the commercial feasibility of reclaiming in profitable quantity any large volume of water by means of very deep wells and "air-lifts" from the great depth of more or less porous mixture of gravel, sand and clay found to probably exist, thru the extensive geological studies of Prof. Branner.

I have had my assistant inspect some of the exposed beds of material classed as gravel by Prof. Branner, and find them nearly impervious as regards practical water supply, the pore space between the pebbles being filled with fine material.

The extremely slow rate of travel of water by percolation in deposits of fine sand is seldom appreciated. A mile a year in medium sand and gravel is a common rate.

Conditions on the Niles Cone

In the body of the report, on page 95, I have presented a plan and section of the Niles Cone showing the relation of the ground water from which the many pumps draw to the shape of the cone and the sources which feed it. Near the outlet of the canyon and along the course of Alameda Creek for several miles are large areas of gravel into which the waters sink and disappear from the creek without continuing on over the clay cap to the sea so long as the flow does not exceed about 30 million gallons daily. The engineers who collected this data were compelled to rely on the existing wells for their data and had but a brief period in which to work and so were unable to trace out the ground water contours fully, but enough data has been collected in the report of Mr. Dockweiler to plainly prove that the cone must look to the periodic outflow from Alameda Creek for a large part of its ground water supply.

Perhaps Best to Defer Building Reservoirs

The question may also very properly be raised, if on a broad view of the situation it will not be better for the cities and for California as a whole to leave all the water that will remain after the Calaveras and Alameda Creeks have been dammed and diverted, for local use in agriculture and manufacture within the Livermore Valley and on the Niles Cone. It is quite possible here as in Los Angeles, in view of the feasibility of bringing a plenty of softer and therefore better water for domestic purposes from the mountains, that this local use for supporting a larger population and building more homes in the beautiful Livermore Valley is the highest use to which these local sources can be put.

It is but fair to write into the record a grateful acknowledgment of the fullness and courtesy with which Mr. S. P. Eastman, Vice-President of the Spring Valley Company, has answered my many questions and opened to my inspection every record or report for which I have asked. I have found in this willingness of Mr. Eastman and Mr. Bourn to show me their data and the reports of their experts, proof of their own sincerity in claiming the large undeveloped resources on Alameda Creek, sufficient for supplying many years of future growth of the city, and of which they fully believed I would become convinced.

On the following pages I present briefly my analysis of certain reports, intended to be helpful in my studies, presented by Mr. Eastman, which he expected would convert me to larger estimates, with the reasons which lead me to a different estimate from that given in these reports of the quantity of water which the cities around San Francisco Bay may depend upon as the utmost practically available in a series of years of low rainfall from the 623 square miles of drainage area on Alameda Creek upstream from the Sunol dam.

A Brief Critical Review of Mr. Schussler's Estimates

Mr. Schussler's remarkable ability and success as a Constructing Engineer and his great length of experience and opportunity for studying the Alameda watershed under the varying conditions of different years, give a special interest to what he has to say in his affidavits before the U. S. Circuit Courts and in his interesting monographs descriptive of the Spring Valley Company's Works, also in his two reports of August 19, 1911, and November 14, 1911, which were submitted for my examination by Mr. S. P. Eastman, Vice-President, Spring Valley Water Company. As one studies his reports it is hard to escape the conclusion that with his many cares and duties, Mr. Schussler's knowledge of this Alameda watershed has been of generalities rather than of details, outside of the narrow portion of the Alameda district covered by the Sunol filter gallery, the Pleasanton wells and Calaveras dam-site.

For example, he does not appear to have ever discovered or investigated the numerous additional rainfall stations found and considered by Mr. Cyril Williams, Jr., nor does he refer to the information developed by means of stream gagings and rainfall records observed by the Bay Cities Water Company, which are quoted by Mr. Williams, nor does he present geologic sections which show the proportions of pervious and impervious strata made up largely from the logs of his own well borers; nor does he present any such diagrams as that on page 87, with its instructive lesson about non-absorption of the sudden floods; nor any such widely extended rain gauge records and stream flow gaugings as those Mr. Edwin Duryea, Jr., has shown me, which he had carried on while studying the possibilities of water yield from Valle, Smith, Isabel and Bonito Creeks.

Scant Data for Accurate Estimates Presented

So far as I have found, Mr. Schussler says nothing to indicate that he has ever made any analytical study of the water resources of the substrata by means of collating the numerous well borings that have been made in the Livermore Valley, such as presented in the sectional drawings of Mr. Williams' report, a few of which are given on page 90, and his optimistic conclusions as to the part that may be played by the broad gravel deposits in storing and carrying over the flow of a wet year for use some years later in time of drought, of itself gives evidence of *lack of detailed study of the limitations* of the substrata, which make it impossible they can provide the necessary amount for equalizing and conserving all the torrents of eighteen years.

I have been painfully surprised in finding how little of precise and scientific information has been collected by Mr. Schussler during his many years of management, from which an engineer can today predict in a dependable way what portion of the widely varying flood flow can actually be stored, regulated and delivered to the cities, properly, for purposes of domestic water supply, and while it is possible from data previously described to obtain estimates not widely in error as to the total yield, it is impossible yet to say just what the size of each new structure must be in order to most economically play its proper part in the conservation, or how much of this total may be diverted permanently.

Almost the only tangible data that I find in Mr. Schussler's two reports are:

(a) The well-known rainfall records by the gage at the Lick Observatory since 1881;

(b) The rain gauge records in Livermore Village since 1875;

(c) Also rainfalls at the Calaveras dam site since 1874, and at Sunol and Pleasanton from 1898 to 1904;

(d) The summary of the daily quantities gaged by the Spring Valley Company at Sunol as waste over its dam, plus the pump records showing what was diverted day by day thru the aqueduct; the same as previously quoted from the court records.

(e) The summary of four years' gagings of the runoff of Calaveras Creek at its proposed dam site. (Very inaccurate.)

(f) A *few* records *of the many borings* that have been made in the valley, which show the thickness of the clay cap over the gravel.

Conspicuously absent are geologic sections like those of Mr. Williams', made by connecting up the Spring Valley's well borings and showing how thin are the porous gravel bodies in relation to the thick clay cap and the many interleaved beds of clay.

The Kind of Data That Should be Now Available

It is a matter of most profound regret that with the resources as its command the Spring Valley Water Company did not many years ago establish daily *accurate* gagings upon Calaveras Creek, Arroyo Valle Creek, San Antonio Creek, and upon Laguna Creek, just below Pleasanton. A dozen more rainfall stations might have been very easily established so many years ago that we would now have a far more accurate idea of the average precipitation over the different tributary subdivisions of the main watershed. All of this information—stream gagings, rainfall records—could have been procured by a small annual expense and with self-recording apparatus, such as clock gages for stream heights, rainfall, etc., costing in all only a few hundred dollars, and without necessarily enhancing land values or hindering the company in its process of gradual acquisition. Clock recording rain gages of the Ollond type and clock height gages for stream discharge can be procured which require a visit for rewinding and change of charts only once a fortnight.

Such information is particularly important and necessary for determining with any reasonable accuracy how the water resources of this valley can be best developed, and what works are required for their conservation in the several subdivisions of the valley, because there is plainly and surely a *very wide diversity in the rainfall* over the various parts of this 623 square miles. We know that the rainfall at the southwest corner of this catchment, on Mt. Hamilton, is double the annual rainfall in the midst of the watershed, near Livermore. We are certain that the Mt. Hamilton range by its altitude extracts the water from the eastward-moving, vapor-laden winds from the Pacific, and that each successive ridge and valley finds less moisture than that which preceded it in the path of the rainstorm, but we have no accurate information which continues over a long enough period to give any very accurate idea of how the rainfall is distributed over the successive ridges and valleys or just how much smaller the rainfall will average in a term of years upon the Valle catchment than upon the Calaveras catchment. So far as Mr. Schussler's reports state, or so far as we can otherwise learn, there have never been *sufficient long-continued gagings of the Valle Creek or the San Antonio Creek* to permit any dependable estimate of their annual total runoff under average conditions, and there is no really good data for telling just how much water they would yield for storage.

We have no observations whatever on the rate in cubic feet per second at which the flood torrents come tumbling down that portion of Alameda Creek which it is proposed to divert into Calaveras reservoir, and therefore n*o one has any accurate information for establishing the proportion of the Alameda flow which would have to escape* because of the well-known rule that a diversion canal can seldom or never be profitably built large enough to carry all of the flood waters. A series of hydrographs of this stream is absolutely necessary for the first step in estimating how much of this flood water can be stored.

Calaveras Gagings Erroneous

With regard to the four years of gagings of the Calaveras Creek at the dam site, of which the annual totals are reported by Mr. Schussler, there is plenty of internal evidence to cast grave distrust on their accuracy and to lead one to believe that they exaggerate the yield of this stream, and I find upon plotting the relation of runoff to railfall given by these gagings year by year that they are strangely at variance with all other reliable records from similar sources, being much too large, and the partial examination of the original notes of these gagings reported by Mr. Cyril Williams, Jr., has brought to light their crudeness and their very serious inaccuracy. Mr. Duryea shows me results of his own gagings on Smith Creek, which drains the seaward face of Mount Hamilton, which give about half the depth of runoff claimed by these Calaveras Creek gagings of the Spring Valley Company.

The Buyer Should Have the Benefit of Doubts

When the owner of a mine, about whose possibilities he is very optimistic, fails to do development work that will accurately outline the ore bodies, the price at which he has to sell suffers correspondingly, and I am disposed to regard a great part of the water resources claimed as available to the cities from the Calaveras watershed, and particularly those from the Livermore district, as in the same class with ore bodies that have never yet been blocked out by proper exploration work, and more than this, I doubt that these available sources exist to any such extent as is confidently believed by the Spring Valley officials. Any such available yield as the 108. million gallons daily estimated by Mr. Schussler is simply an impossibility, in view of the other facts that he presents.

The questions and doubts relate to the future enlargement of this supply, not to its present quality. The development of the Alameda ground water is an admirable work, and the water is of excellent sanitary quality, clear, white and very attractive, though somewhat hard, but there is grave question if much more of the same quality can be taken here.

A Difficult Region for Water Estimates

In the absence of accurate gaugings one can sometimes make tolerable estimates from rainfall and catchment area.

This 623 square miles of the Alameda watershed is a particularly difficult one in which to estimate the runoff from scattered rainfall records, or by comparison of the area of its various subdivisions with the area of catchments whose yield per square mile has been accurately measured. This can be judged by an inspection of the relief map at the beginning of this report.

The quantity of rain per square mile falling on different portions of this catchment is vastly different; for example:

Year.	Mt. Hamilton.	Livermore.
1889-0	45.2 inches.	28.7 inches.
1892-3	43.3	23.1
1906-7	37.9	26.3
1897-8	17.7	9.1
1907-8	23.9	9.9

If months or single storms were compared the results would be much more erratic. The difficulty of estimating the runoff within fifty per cent from rainfall records, in the lack of long-term local observations, is increased by the local conditions and by the fact that the percentage which the runoff bears to the rainfall is far more scant, uncertain and capricious under rainfalls of from 15 to 20 inches than it is in regions where the average rainfall is larger and more evenly distributed over the various months of the year.

In this particular territory, much of which is of a semi-arid character, several small rainfalls which would aggregate one inch in the monthly record, may readily happen to come under conditions such that each of those small rains will nearly all evaporate soon after it falls. On the other hand, a violent rapid precipitation amounting to an inch, all in the course of a single night, or within a few hours, may in a large measure be delivered into the stream and give rise to a brief, raging torrent that will cut a large figure in the yearly runoff, but which *comes with such a rush that it cannot be conserved in the valley gravels.*

The Vagaries of the Local Rainfall

By studying annual totals of the particular gagings given by Mr. Schussler, it will be noted that the percentage which his record of the runoff bears to his average of the annual rainfall recorded for the same years at Mt. Hamilton and Livermore, varies in the most erratic way.

In general, the relation of runoff to rainfall is much more erratic and uncertain in a region of high temperature and small atmospheric moisture than it is where snows serve to store the winter precipitation and where there is a surplus of rainfall over and above what is required and eagerly seized on by vegetation.

While studying the following table it is of interest to remember that Mr. Schussler's use of the straight average of the Mt. Hamilton and Livermore records exaggerates the average rainfall over the district as a whole, as worked out in great detail by Mr. Williams.

Selecting from the table some years when the total rainfall found by averaging Mt. Hamilton with Niles, was near the general average of 20 inches, we find violent disagreement in the runoffs measured by the Spring Valley Company at Niles or Sunol, as below:

Year.	Rainfall, inches	Runoff, inches	Per cent. of rain that ran off
1891-92	19.4	1.8	9.
1893-94	20.4	5.2	25.
1895-96	21.0	3.5	17.
1902-03	19.5	2.2	11.
1903-04	19.3	3.4	18.
1904-05	21.8	1.9	9.

Selecting the years of smallest runoff, the rainfalls that produced them were as follows. Note how they vary, particularly the last two, which show the same runoff with very different rainfalls:

Year.	Rainfall, inches	Runoff, inches	Per cent. of rain that ran off
1897-98	10.7	0.8	7.
1899-00	18.5	1.7	9.
1900-01	19.4	1.8	9.
1901-02	18.6	1.8	10.
1904-05	21.8	1.9	9.
1907-08	14.9	1.9	13.

By reason of the above irregularity it is plainly impossible to deduce the unknown run-off in any particular year even if we had accurate knowledge of the rainfall for this region as a whole, and is still more difficult to deduce the run-off per square mile in any particular subdivision of this mountainous catchment area, where rains are capricious and variable, with elevation and exposure to winds from the sea. It is speculative and the result uncertain within wide limits.

Note the wide diversity of the per cents in last column of table below.

The per cent of run-off in one heavy rain will be far greater than the aggregate run-off from five or ten slight rains which might aggregate the same amount in the monthly record and each of which would evaporate almost as quickly as it fell.

Deductions as to yield of water available for municipal supply that may be made from these rainfall data are speculative and the element of guesswork too large.

SOME RECORDS OF RAINFALL AND RUN-OFF ON 623 SQUARE MILES ABOVE SUNOL.

Seasonal year divides Nov. 1, until 1904, subsequently on July 1.	Average run-off at Sunol, equivalent million gallons daily for the year, as gauged by the Spring Valley Co.	Total annual rainfall at Mt. Hamilton, inches.	Total annual rainfall at Livermore, inches.	Average of these two.	Average rainfall for entire catchment area as deduced by C. Williams, Jr., from careful study of scattered gauges.	Excess of straight average of Mt. Hamilton and Niles.		Total inches depth of run-off, from gaugings of the Spring Valley Company near Sunol.	"Fly-off" or evaporation, being difference between the rainfall and the run-off, inches depth.	Per cent of run-off gauged by S. V. Co. to average rainfall as deduced by Williams.
					Inches.	Inches.	Per cent.			
1889-90	426	45.2	28.7	36.9	35.5	1.4	4	14.4	11.1	40.5
1890-91	96	24.1	14.2	19.1	16.2	2.1	16	3.2	13.0	18.0
1891-92	52	27.5	14.2	20.8	19.4	1.4	7	1.8	17.6	9.3
1892-93	279	37.9	26.3	32.1	29.2	2.9	10	9.5	19.7	32.5
1893-94	151	35.8	17.2	26.5	20.4	6.1	30	5.2	15.2	25.5
1894-95	224	36.6	24.4	30.5	28.7	1.8	6	7.6	20.1	27.4
1895-96	102	29.8	16.4	23.1	21.0	2.1	10	3.5	17.5	16.7
1896-97	174	32.2	17.3	24.7	23.1	1.6	7	5.9	17.2	25.5
1897-98	10	17.7	9.1	13.4	10.7	2.7	25	0.3	10.4	3.2
1898-99	68	25.7	9.3	17.5	16.2	1.3	8	2.3	13.9	14.2
1899-00	50	29.3	12.7	21.0	18.5	2.5	14	1.7	16.6	9.2
1900-01	88	31.6	19.7	25.1	24.1	1.0	4	2.9	21.1	12.0
1901-02	54	27.6	16.8	22.2	18.6	3.6	19	1.8	16.8	9.7
1902-03	64	30.3	14.3	22.3	19.5	2.8	14	2.2	17.2	11.3
1903-04	101	33.8	13.3	23.5	19.3	4.1	21	3.4	15.9	17.6
1904-05	56	28.6	15.8	22.2	21.8	0.4	2	1.9	19.9	8.7
1905-06	173	38.4	19.3	28.8	25.0	3.8	15	5.6	19.4	22.4
1906-07	278	43.3	23.1	33.2	29.1	4.1	14	9.5	19.6	32.7
1907-08	58	23.9	9.9	16.9	14.9	2.0	13	1.9	11.9	12.7
1908-09		37.4	18.6	28.0	25.2	2.8	11			
1909-10										
1910-11										

From the above it is seen that the method of computing the average rainfall on the Alameda watershed used by Mr. Schussler, by simply averaging the Mt. Hamilton and Niles gauges, ranges from 2 per cent to 30 per cent more than the average worked out from all available gauges, and averages 12½ per cent greater.

The Strange Relation of the Gaugings at Calaveras to Sunol Gaugings of Total Flow

A lack of dependability in the Calaveras gaugings of the Spring Valley Company is indicated by the following comparisons:

Seasonal year.	Total annual run-off gauged at Sunol, 623 square miles.	Total annual run-off gauged at Calaveras dam site, 101 square miles.	Corresponding daily run-off at Sunol, 623 square miles.	Corresponding daily run-off at Calaveras, 101 square miles.	Flow from remaining 522 square miles by difference.
	Mil. gals.	Mil. gals.	Mil. gals.	Mil. gals.	Mil. gals.
1904-05	20,254	16,543	55.4	45.3	10.1
1905-06	63,134	32,551	173.0	88.6	84.4
1906-07	102,917	54,507	282.0	149.2	132.8
1907-08	21,189	14,147	58.0	38.7	19.3

In the above records it is to be noted that in the year 1904-05 about five times as much water was gauged coming from the 100 square miles of the Calaveras watershed as came from the remaining 523 square miles. In other words, the *rate of run-off per square mile was twenty-five times as great* on the Calaveras watershed as on the remainder according to these gaugings.

Similarly, during the year 1907-08, the run-off gauged as coming from the 100 square miles of Calaveras was about twice as much as that which came from the remaining 523 square miles, or more than ten times as great a yield per square mile.

In the very wet year, 1906-07, the quantity coming from the hundred square miles of the Calaveras was substantially equal to the quantity that came from the remaining 523 square miles, or more than five times as great a yield per square mile.

If these figures were accurate, it would be impossible to believe that in the year 1904-05 with only 10.1 million gallons from all outside of Calaveras, the Spring Valley Company could have supplied any larger amount from the Pleasanton region than it is now taking.

The Intake to the Gravels

I note from going over the ground incompletely that the area of bare, open, gravelly creek bed is much smaller than the broad square miles classed as gravel intake on certain of the maps, and the proof of the inefficiency of the intake to the subterranean storage to drink in the water that flows over these beds is found in the floods which escape down Laguna Creek, and in the fact that *a large part of the total volume of the year's run-off comes along in these floods.*

A study of the relation day by day of the record of run-off at Sunol following each important rainfall is interesting in showing how quickly the limit of the absorptive power of the gravel intakes is reached. Similarly along Alameda Creek near the top of the Niles Cone the limit of capacity to absorb flood flow appeared to be reached at about 30 million gallons daily, which is a small fraction of what comes along in a flood.

Irregularity of Flow Proves Absence of Natural Storage

The lack of regularity in run-off gauged at Sunol shown in the table of yearly totals from 1889 to 1908-09, presented by the Spring Valley Company, makes it incredible that the broad gravel deposits near Pleasanton and Livermore can play anything like the part in regulating the outflow which has been claimed for them, by storage in their porous spaces.

Note, for example, that in the seasonal year 1889-90, which had the greatest rainfall (35.5 inches) and had the greatest run-off of any year yet recorded, was followed by one in which the run-off was less than one-fourth part as great as in the previous year. Similarly, the year 1906-07, with a rainfall of 29.1 inches and a run-off of 103 billion gallons, was followed by a dry year in which the total run-off was only 21 billion gallons, or one-fifth part of that in the year previous.

The year 1896-97, with an average rainfall of 23.1 inches and a run-off of 63.5 billion gallons, was followed by the very dry year 1897-98, in which the total run-off for the year was only 3.6 billion gallons, or only one fifty-sixth part of the previous annual delivery.

Conversely, the prompt response to a heavy rain in increased flow shows that much water avoids sinking into the gravels.

There is a totally different relation of variability of run-off here from wet season to dry from that which I have found where large underground storage really exists, in porous volcanic ash deposits upstream from Big Meadows, California, or on the Pitt River.

It is plain from the records of variable flow that whatever run-off from Arroyo Valle and Arroyo Mocho as they issue from the steep mountain valley and flow across the plain sinks into the broad gravels does not stay there and store itself under the natural conditions so as to increase to any noteworthy extent the yield of the dry years which followed. A study of the swelling yield in January and the gradual diminution in June, July and August shows plainly that the period of storage in the gravels *is one of only a few months' duration, and that the absorption is never complete.*

A study of the topographic map and a superficial examination of the region must lead one to expect that any storage in these gravels would be relatively brief and of small effect in carrying over the surplus of a wet year for use in extremely dry years, unless it can be proved that the gravels are porous to great depth and continuous enough so that water will flow readily from one part of the bed to another and unless wells are sunk and pumped so far below the rim of the basin that the drained space will hold all that comes down in a wet year. Also, it must be proved that the surface exposure of gravel is broad and porous enough to drink in the flood as fast as it comes along.

The very fact that raging torrents sometimes pour down these stream beds, past Livermore and Pleasanton, of itself proves that the capacity of these gravels to take in the rapid flow following a heavy rainfall is extremely limited, and the topographic map of the United States Geological Survey plainly shows that the downstream edge of this gravel storage basin is about elevation 320, while the upstream corner of the basin is at about elevation 470 in the case of the Valle and 550 in the case of the Mocho, and upward of 600 at the extreme upper edge of the gravel floor. In other words, the gravel intake is 150 to 230 feet higher than its outlet, thus giving a great incentive for the upper layers of the gravel to soon drain out, as indeed the hydrograph shows they do, in the course of a very few months. (See diagram on page 87.)

Mr. Schussler's Isohyetal Lines

Certain rainfall charts presented by Mr. Schussler compared with the studies presented by Mr. Williams, are crude affairs. It is plain on examining them carefully that his lines of equal rainfall for the several years have been drawn with a bold, free hand, and while I have no doubt they represent the broad, general tendency, it is certain they are not at all precise, for a study of the relief map shows that the average rainfall contours must twist and turn around, paying far more attention to the altitudes at different parts of the area than is indicated by Mr. Schussler's charts.

Still it is a far simpler matter to approximate what this rainfall is over these areas and to roughly approximate what this rainfall will average for a long term of years at a given spot than it is to say what proportion of this rainfall would become available as run-off from that particular subdivision. *This run-off proportion is extremely variable and uncertain.*

Relation of Rainfall to Run-off

Mr. Schussler's rule for finding the run-off for the several subdivisions into which he divides the total area of 653 square miles for purpose of estimate, apparently rests simply on his personal judgment, and he presents no logical argument by which another engineer can arrive at the same results, or can check up his deductions.

To begin with, his areas are a little larger than those shown on the latest maps. His rule for estimating the gross precipitation simply averages the rainfalls observed at the Lick Observatory and at Livermore for the year in question. This average of the two is probably 12½ per cent larger than the actual average rainfall over the whole watershed (see table). Then, he works out a percentage for the ratio of the run-off to the rainfall for each subdivision which looks to him reasonable (but which I assume is influenced by the erroneous Calaveras gaugings). These percentages are based on Mr. Schussler's "judgment" and on nobody's accurate measurement.

All through this attempt to show that the Spring Valley owns vast undeveloped resources which would supply the growth of the city for many years, I find a vast amount of speculative philosophy and a sad lack of cheap simple measurement such as the water company had it in its power to have made for twenty or thirty years past.

Error of Relying on Long-Term Averages

It appears absurd to figure that all of the great quantity of water which he estimates as available, could be so conserved by the natural gravel storage plus the artificial storage which he proposes of thirty billion gallons in the proposed Calaveras reservation, eight billion gallons in the San Antonio reservoir, and twelve billion gallons in the Arroyo Valle reservoir, so that not a gallon would run to waste down the Niles Canyon during the long period of eighteen years.

In problems of water supply we must always be limited by the amount that is dependable in a series of years of low rainfall. It is never proper to base such estimates upon the average run-off for a long term of years.

The effect of these long-term averages is always to smooth out the sharpness of the fluctuation between wet years and dry and to lead to an exaggeration of the quantity which can be supplied in time of extreme drought.

Inadequacy of Storage at Sunol

That the Sunol filter area of porous gravels cannot be of any material assistance in the storage and carrying over of water from a wet year to be used in a dry year may be seen in a common sense way by noting its area as shown on Mr. Schussler's map in comparison with the area of the proposed Calaveras reservoir, and by reflecting that the bottom of these porous gravels is said to have been reached when building the concrete filter gallery, which I am told *has its foundation resting for nearly its entire length upon a hard, impervious stratum of mingled gravel, sand and clay* underlying the stratum of porous gravel, and it is pictured with an impervious bottom in the very interesting advertising pamphlet of the Spring Valley Water Company.

I would not be understood as failing to appreciate the fact that the Alameda properties of the Spring Valley Company form a magnificent water supply system, developed thus far with great wisdom, skill and foresight and furnishing today 17 million gallons daily of water of admirable sanitary purity (though hard). My present report relates chiefly to the *additionol extent* to which these sources can be developed, which I believe is greatly over-estimated by the Spring Valley officials. With true paternal fondness Mr. Schussler over-estimates the capabilities of his child.

Gravel Storage Probably Over-Estimated

After very carefully reading all of the reports submitted by the Spring Valley Company and also studying the data collected by the city, I find no evidence to disprove the idea that this *porous* gravel deposit probably is simply a vast, broad, shallow, irregular multitubular sort of conduit, for or five miles in length, into which, during periods of *low flow, and low medium flow*, all of the waters of the Valle and Mocho Creeks sink and disappear downward at the large porous gravel outcrops, which are found where the steep mountain valleys meet the gentle inclination of the plain.

But there is abundant proof that the mouth and the conduit space with the pores of these gravels have not capacity to drink in more than a fraction of the flow that goes down the mountain valleys in the time of great flood, and therefore this unabsorbed portion of the flood flows down over the surface, along the bed of the creek *above the clay cap*, finally reaching Laguna Creek *without any possibility whatever* that all of the run-off of the wet year, 1892-93, for example, could have all been conserved by storage in the gravels.

The portion of water which is absorbed into the gravels percolates slowly downstream through the bed of gravel, but all indications are that the great bulk of it traverses its course of four miles, more or less, in much less than a year's time, and then reappears in the swamps near Pleasanton. The fact brought out by the Spring Valley's records of yearly, monthly and daily flow at Sunol and the rapid shrinkage in the rate of flow after a heavy flood, plainly shows that this situation is very different from that presented in some parts on California, Texas and Montana, where I have observed springs of great volume coming from subterranean storage, with slight fluctuation in the course of the year as the dry season followed the wet season. Here the *rapid chonge in rate of flow* from February to August is *proof positive of the limited detention* by storage in the gravels.

The diagram on page 87 is of great interest in this connection and the same facts are shown year after year in plotting the comparisons of rainfall and run-off.

It may, of course, be argued by Messrs. Schussler and Mulholland from the great depth of the refilled pocket disclosed by Professor Branner's extremely valuable geological studies that one might sink wells almost without number into this vast gravel deposit, which has "more than 1,000 feet of depth," and so draw down the subterranean reservoir during a series of dry years that the flow of the following wet year would all be used to replenish this depletion; but neither in Dr. Branner's report nor in Mr. Schussler's report, are there any satisfactory data presented which would tend to disprove the probability that by far the greater part of this deep deposit *possesses very little of porosity available for storage* or suitable for prompt release of the stored water by pumping.

Probability That Deep Beds Are Impervious

It is a matter of general experience that where coarse gravel deposits are laid down by quick-moving streams as they leave their steeper mountain courses and travel with much smaller velocity across the lesser slopes of the plain, that the channel in the plain is subject to much meandering and shifting, with a result that the coarser gravels are commonly laid down in separate, lune-shaped beds, each at some eddy or "ox-bow" in the stream and that after a relatively small area has been thus covered with loose, coarse gravel, the stream during some freshet will make a short cut across the neck of the loop, leaving the previous gravel deposit to be slowly covered and surrounded by finer impervious material, such as deposits in eddies.

There is ten-fold more reason to expect that the gravel deposits laid down in the localities described are mainly detached lune-shaped masses, or "kidneys," with uncertain obstructed connections, through which the delivery of stored water from one link to another would be very slow, than there is for supposing it all a vast, homogeneous mass, as would be required to support the estimates presented by Mr. Schussler.

When comparing the fluctuation of the plane of saturation at one well with that at neighboring wells, it must be continually kept in mind that while it is possible that two wells, some hundred yards apart, will tap the same porous lune or kidney of porous gravel, any number of other wells in the vicinity might happen to not tap the same bed.

While one must recognize that there were good business reasons why the Spring Valley Company could not enter upon lands which it did not own and make extensive borings, there were many ways in which it could have, during the past ten or twenty years, quietly accumulated a vast amount of definite information which would be of great value at the present time. The simple averaging of floods and droughts in statistics does not insure the possibility of a uniform daily supply.

From a study of the rainfall records at Mt. Hamilton and that at Livermore and from their own observations upon the varying character of the vegetation in different parts of the territory which they inspected, Mulholland and Lippincott make out a table of their own of the average rainfall in the different portions of the valley, with the areas in square miles of each portion to which this average pertains, and having satisfied themselves about the accuracy of this average rainfall, they take a well-known but loosely established curve published in the U. S. G. S. Water Supply Paper No. 81, page 17, designated as a "*general* curve for large watersheds," which was intended to represent general or average conditions in California, and applying this curve to their depth of rainfall they deduce the depth of run-off for each subdistrict, which multiplied by the square miles in each subdistrict, gives the quantity which the said subdistrict can yield.

This method happens to bring out a result very near to Mr. Schussler's estimate of the yield, but *I would most strongly protest against any such method being a reliable one* for giving accurate results. It was simply a very rough, broad generalization, which often falls wide of the mark.

The engineer who devised this curve had extremely little data to guide him in drawing that part of the curve where the rainfall is so small as it is in the Livermore Valley, and the vagaries found in this particular region and described in pages 194 and 195, preceding, shows how utterly unreliable is the use of such a generalization in this case.

Some years ago when studying a large water power development on the Feather River, I made a careful analysis of all of the data presented in Water Supply Paper 81, and of much other data, and found it very plain that the quantity of run-off which could be obtained from a given depth of rainfall where the total annual precipitation was only from ten to twenty-five inches per year, is *extremely capricious* and is *subject to the widest kind of variation* on different watersheds and on the same watershed in different years.

How grossly vague such a method is, can be judged by a comparison of the curve selected by Mulholland and Lippincott from Water Supply Paper No. 81 (which paper was prepared by this Mr. Lippincott), with a curve that I have drawn from the actual records for this patricular region, kept for nineteen years by the Spring Valley Water Company. It will be seen that in the several individual years the results of measurements depart widely, and without rule or reason, from the curve that has been adopted by Mulholland and Lippincott, in deducing the yield of the Livermore region and the fact that their result happened to come out nearly the same as Mr. Schussler's *really proves nothing at all.*

In the effort to make a proper deduction on account of the evaporation loss from the swamp lands north of Pleasanton, the authors have recourse to their own observations from moist lands in the Owens Valley and assume that the evaporation from water surfaces in the Livermore Valley would be only 40 inches in depth per year, and that the evaporation from wet ground with saturation three feet beneath its surface would be 55 per cent of that from an open water surface in the same locality.

It should be noted that the Owens Valley observations were made at an altitude of some 4,000 feet above sea level, where the night temperature is very different from that during the day, and where the mean annual temperature is so much less than at Livermore as to lead one to anticipate far more evaporation at Livermore than at the site of their experiments. They make no proper allowance for this great difference in temperature and conditions. I have myself made extended experiments on evaporation at high altitudes in California, possibly the most elaborate that have yet been made, and found by my psychrometer as well as by micrometer measurements of the depth in my evaporation tanks that at night at high altitudes, the air becomes quickly chilled and that evaporation then almost stops. In the warm winters and warm summer nights of the Calaveras, Antonio and Valle sites the winter evaporation and the night evaporation would be very much larger.

In their estimates of drainage from the voids in the sands and gravels, presented on page 8 of their report, they present an estimate so hasty and crude that I am pained to find the names of my good and able friends attached to it. They have absolutely no justification, which I can find, for assuming that 35 per cent of the volume *may be drained out* from the voids *in the average sands and gravels of this valley*, and most certainly they have no basis for their belief that the denser overlying soils, constituted mainly of clays, "would give up 10 per cent of their volume in water," under any possible system of water supply development. I regard these figures utterly unwarranted for these circumstances.

They also utterly overlook the probability that the gravel deposits do not lie continuous, but most probably lie in kidneys (as is confirmed by Professor Branner), so that they cannot be rapidly drained by any practicable well system.

Their own personal seepage observations are on interest as far as they go, but comprise only two observations, namely, that on January 27, 1912, following a rainstorm of the day previous, they witnessed a flow of 45 second-feet measured at the clay bridge on the Arroyo Valle, all sink into the gravel bed of the river within three thousand feet length of channel below the bridge. On the same day they found ten second-feet flowing in the Mocho at the mouth of Dry Creek, which all disappeared within a mile. They display these two little isolated observations and ignore such facts as shown in diagram on page 87, and of which there are dozens of instances in the records to which they had access.

It may be worth while to criticize the statement on page 11, of their report, about the gravel which fills the valley, "that since the material was transported entirely during the periods of high flow, it is mainly composed of clean materials, as the finer products of erosion were carried away in suspension to the sea." That they were not carried to the sea is shown by the vast deposits of clay over the downstream end of the Livermore Valley and the clay cap of the Niles Cone, and by the plugging up of the downstream end of our multitabular gravel conduit, causing the artesian condition.

May we ask *what becomes of the particles of sand and silt* and the small particles of gravel that have been the cause of making these flood waters turbid during the floods of the past few years?

When the turbid water disappears into the porous gravel and comes out as beautifully clear, filtered water a few miles downstream, surely *the sand and silt that caused this turbidity must have been caught and detained within the pore-space* of the coarser gravel which was first brought down. Beyond all doubt or question a large part of the original pore-space between the coarse pebbles has *become packed full of silt* in this manner. The artesian condition found formerly before heavy pumping began at Pleasanton and on the Niles Cone near Alvarado is plainly the result of, first, a clay cap having been deposited on top of the multitubular gravel conduit, and, second, of the lower end of the gravel conduit having become clogged by silt.

On page 13 of their report, the authors conclude that the alluvial deposits and the clay cover is far from impermeable.

If this were the case, why should the flood wave rise to such sharp peaks after a rapid fall of rain?

Summing up my conclusions I can find nothing in the data, or in the reasoning, presented by Messrs. Mulholland and Lippincott, or in the much more complete data presented by some of the others who have studied this region, which gives any reasonable basis for the conclusion reached by Mulholland and Lippincott on page 20 of their report, that by means of wells and pumping, "and without the construction of the Arroyo Valle reservoir, from 35 to 40 million gallons per day of continuous flow can be developed from the gravel beds of Livermore Valley."

I am led to believe that the best of the evidence surely proves that less than half this quantity can be so obtained.

A Brief Review of Dr. Branner's Report of December 1, 1911

In my visit to the Livermore Valley in last August I had the pleasure of Professor Branner's instructive company, and he pointed out much that was extremely interesting regarding its geologic history. His report of December 1, 1911, has been handed to me by Mr. S. P. Eastman, Vice-President of the Spring Valley Water Company, for my further information.

There is no man living better qualified than Dr. Branner to speak with authority upon the geology of this region and his conclusions regarding the origin of this deep basin and its refill, which forms the present floor of the valley, appear so reasonable that they may be accepted without question.

But after studying Professor Branner's report carefully, I am still unable to concur in the extremely optimistic views of Mr. Schussler, Mr. Lippincott or Mr. Mulholland regarding the volume of water which can be stored from the sudden floods sinking into these gravels and reclaimed for the domestic supply of the cities.

Professor Branner himself makes no suggestions as to the quantity of water, save to describe it in indefinite terms as "very large."

Of the various materials that have been washed in from the surrounding hills, forming the valley refill in which these wells were driven, he finds that the clays have the widest distribution, and the greatest thickness; that the sands are next in abundance, and the gravels last in order of abundance. That the materials vary greatly in thickness and alternate with each other variously.

Three of his conclusions that are particularly important in our present study are given on the third page of his report:

(1) "*The pockety or uneven distribution of the gravels* suggest that they have been carried to their present resting place by streams."

(2) "All the available data go to show there is no *single widespread water-bearing gravel bed* beneath the valley floor."

(3) "*The water-bearing beds are lenticular* and more or less irregular; though they appear to follow the lines of the ancient and shifting drainage as if it had swung from one part of the valley to another."

Each of Professor Branner's conclusions stated above, tends to confirm the views that I have expressed in my report about the limitations to the available storage of water within these gravels.

Professor Branner's statements as to the water-bearing character of the deep gravels are distinctly qualitative, *not quantitative*, but so far as they go they tend to confirm the statements and conclusions of Mr. Cyril Williams, Jr., as set forth in his geological cross-sections, which sections show the water storage space in the porous gravels to be far too small to store the volume required for storing and equalizing the floods of eighteen years.

The lenticular form of the beds mentioned by Professor Branner and their irregularity render them far less available for purposes of subterranean storage, with rapid absorption and ready delivery to the wells than if they lay in a single widespread continuous water-bearing gravel bed.

Open Pore Space is Necessary for Water Storage

Although we accept without question Professor Branner's conclusion that the westerly part of this great basin, miles in extent, has its rock bottom more than a thousand feet below the present valley floor, and concur that the refill is composed chiefly of gravel, the breadth and depth of this vast mass of gravel proves nothing as to its availability for water storage for municipal purposes and for conserving the flood flow of these extremely variable streams until we have definite knowledge about the volume and size of its pores. One does not buy a mine on the basis of a generalized geologic map. Such evidence is useful but not conclusive.

The well-borer commonly records a material penetrated as "gravel" regardless of whether it is pervious or impervious, or how completely the pores between its coarser pebbles are filled.

The coarser stones, larger than hens' eggs, may have their interstices filled with smaller stones, the size of marbles, and the interstices between these may be filled with smaller gravels, the size of small peas, and these in turn have their interstices filled with sand grains smaller than grass seed, and the interstices between these sand grains be filled with clay. In this case the whole would form a compact impervious mass, which would be absolutely useless for the conservation of a variable water supply, although so saturated that it would show 20 per cent or more loss in weight when carefully dried in the laboratory.

In order to be useful for the purpose of regulating stream flow, not only must the gravel bed be of vast extent and be chiefly composed of very coarse pebble-gravel—it must have the interstices between the coarse pebbles *open, effective and available for receiving an inflow of water rapidly and for its rapid delivery to the pump.*

The rate of flow of water through coarse sands that have no admixture of clay is far more slow than is popularly appreciated; one mile per year is not an uncommon rate. Obviously the underground reservoir must give up its water far more rapidly than this if it is to be useful under such conditions as are found in the Livermore Valley.

None of Professor Branner's conclusions conflict with the plain, common-sense view that the pore-spaces within this vast deposit of gravels must have long ago become largely filled with the finer particles. The fact that today water drawn from the gallery at Sunol and from the wells at Pleasanton is beautifully transparent and free from all trace of turbidity, while streams which pour down the valleys in time of flood are highly turbid, is of itself a proof that in the thousands, or hundreds of thousands, of years during which the refill of the valley basin has been going on, *the filtering gravels have been in the process of becoming clogged*, and the fact that as shown in the accompanying section, taken from Professor Branner's report, the level of the gravel bed, where the floods issue from the mountain valleys, is two or three hundred feet higher than the surface of the stream near Sunol and that vast areas of open, porous gravels are exposed in the stream beds so as to drink in whatever they can of the turbid flow, which they discharge later as clarified water at the Pleasanton wells or into the Pleasanton lagoon, proves that this process of clogging this filter must be going on still.

Professor Branner's report, page 4, emphasizes the fact of the peculiar seasonal distribution of the rainfall in this region. The great volume and velocity of the streams, especially the Mocho and the Valle, which together drain a mountainous area of more than 215 square miles and head about an elevation of 3,000 feet, enables them during the flood times to sweep down and out, not only the sands and gravels, but even large boulders, and in large quantities, and this arrangement also enables the lesser quantities of water flowing at other seasons to sink promptly into these coarse gravels and to gradually move toward the lowest part of the valley.

It appears to me that this statement plainly confirms the view which I have previously indicated, that while these gravels can absorb the relatively small summer flows and conduct them slowly downstream beneath the clay cap, somewhat as in a multitude of little pipes, toward the Pleasanton wells or the old Pleasanton lagoon, this structure of the ground is utterly incompetent to absorb and store the large portion of a great flood, much less to absorb them so fully that not a gallon from the Mocho, Pescadero, etc., would be wasted during the long period of eighteen years, as is estimated by Messrs. Schussler and Mulholland.

One of the most important and gratifying results of Professor Branner's investigation is his conclusion, stated on page 8, that the contour of the present surface of the ground and the relations of that surface to the present valley outlet through the Niles Canyon, make untenable any theory that there may be an underground outlet for the waters of the Livermore Valley northward through the San Ramon Valley.

Finally, comparing Professor Branner's report carefully with the data presented in the well-boring records shown in the report of Mr. Cyril Williams, Jr., I find nothing that tends to contradict the data presented by Mr. Williams.

Paragraph No. 15 of Professor Branner's conclusions is of particular interest, namely:

"It is quite possible that further geologic studies may develop the fact that deep artesian wells may be found by sinking into the older gravels near the foot of the hills east of Pleasanton." As yet this is merely a hopeful possibility and can have no important part in an estimate of the value to San Francisco of the sources now controlled by the Spring Valley Water Company.

It is well to remember that *human nature, east and west, is found extremely optimistic as to underground water sources, much as it is with regard to other kinds of mining*, and that in the whole history of water supply engineering the number of cases of successful artesian wells giving a volume sufficient to be of material use in the supply of a large city, are extremely rare.

I have visited and studied the region in which Mr. Mulholland is developing underground water by deep wells along the western edge of the Owens Valley, at the base of the delta cones, and I consider the conditions there to be very different from those found in the locality now in question. There at the base of the great eastern fault-scarp of the granite Sierras, the pebbles and sand grains resulting from the attrition, and water-sorting of material cracked off by frost from the hard primitive rocks are surely more likely to be open and porous at the foot of the steep delta cones, than those on the more level floor of the Livermore Valley, resulting from the re-working of the softer ancient, sedimentary material of this portion of the Mt. Diablo range.

Appendix No. 5.

The following is an abstract of the conclusions found in an investigation described in a report of 410 pages with 42 sheets of well logs and 70 diagrams, prepared to be filed on August 1, 1912, with the Advisory Board of Army Engineers for the Secretary of the Interior, in response to his request to show cause, etc.:

July 27th, 1912.

Percy V. Long, Esquire,
City Attorney,
San Francisco, Cal.

Sir:

There is herewith submitted you report on the water supply of the Niles Cone, Alameda County, California, prepared at your request, following the call by John R. Freeman, C. E., for definite facts and figures with regard to the ground water supply of this region.

As the result of the investigations conducted in the field from May 21st to July 15th, 1912, and office studies since latter date, the following statements are presented:

Alameda Creek is the source of water supply for the Niles Cone gravels. These gravels receive the Alameda Creek waters through percolation.

About 1500 wells are now in use, extracting the waters from the cone gravels.

The total quantity pumped from the cone last year averaged daily...........	14,000,000 gals.
Of this, the daily use upon the cone averaged	5,500,000
Sent outside the cone......	8,500,000

To Oakland by People's Water Co.	8,000,000
To Hayward, by San Lorenzo Water Co. ..	500,000

The area of the Niles Cone is about 74 square miles, equal to 47,360 acres. Excluding the Coyote Hills, area 1,280 acres, there remains 46,080 acres, segregated as follows:

Salt marsh lands........................	16,000 acres
Farming Lands	28,160
Town and village sites..................	1,920

Of the salt marsh lands about two-thirds, 10,700 acres, will probably be reclaimed and require irrigation within the

THE NILES CONE AND ALAMEDA CREEK.

Panoramic view looking westerly toward San Francisco from the hill slopes near the outlet of the Niles Canyon.

next thirty-five years. About 1,500 acres have been reclaimed to date—an experimental farm on the Oliver Salt Works lands demonstrating the possibilities.

The area of irrigable land, including area of communities, is about 40,780 acres; 80 per cent of this, or 32,500 acres, will ultimately require irrigation.

Two acre-feet per year is assumed as the duty of water.

The amount of return water, i. e., water which can be used a second time, by recovery through pumpage, is estimated at 1,600 acre-feet.

The estimated total annual quantity of water required for irrigation with the maximum area irrigable in any one year—32,500 acres—irrigated, is 63,400 acre-feet, which equals 56.7 million gallons daily flowing one year.

The total annual average discharge of Alameda Creek, including the quantity sent to San Francisco by the Spring Valley Water Company, during the critical six consecutive years of low rainfall, beginning with the year 188 and ending with the year 1903, was........... 56 mil. gals. daily.
The minimum year, 1898, being... 10 mil. gals. daily.
The maximum year, 1901, being... 85 mil. gals. daily.

The Spring Valley Water Company began to divert water from Alameda Creek in 1888 and has sent to San Francisco quantities of water which have gradually increased, as follows:
Year 1888, annual average...... 1.25 mil. gals. daily.
Year 1911, annual average...... 15.59 mil. gals. daily.

The average annual replenishment of the Niles Cone from Alameda Creek, before diversion to San Francisco took place, as testified to by Messrs. George F. Allardt and Ross E. Brown, Civil Engineers appearing on behalf of the Spring Valley Water Company, in the "Clough vs. Spring Valley Water Company" litigation, is given as......... 29½ mil. gals. daily.

Projects of the Spring Valley Water Company embrace the construction of three large storage reservoirs in the Alameda Creek watershed, with drafts upon Pleasanton wells storage. If these projects had been completed at the beginning of the eight critical seasons, 1897-98 to 1904-05, inclusive, with all reservoirs full, and 29½ million gallons allowed to flow upon the Niles Cone every day, there would have been available for diversion to San Francisco during the eight seasons, an average of... 36.3 mil. gals. daily.
Varying from a minimum in 1897-98 of .... 23.1 mil. gals. daily.
To a maximum in 1903-4 of..... 47.2 mil. gals. daily.

The low water flow of Alameda Creek during each summer has been practically all diverted to San Francisco.

The estimated storage capacity of the Niles Cone, above mean sea level, available for water that can be drawn therefrom by pumping, is as follows:
To present water table, June, 1912.... 6,130 mil. gals.
With present water table 20 feet higher.. 9,040 mil. gals.
With present water table rising to surface ....11,400 mil. gals.

For Comparison.

The Crystal Springs reservoir of the Spring Valley Water Company has a storage capacity three and one-half times as great as that of the Niles Cone water table of June, 1912, and the proposed Calaveras reservoir of the Spring Valley Water Company will be about five times as great.

The ground water or water table has lowered over the cone since the Spring Valley Water Company began diverting water to San Francisco—evidenced by wells in the marsh or lower area. These wells were formerly artesian; they have now ceased to flow. The drying up of springs is further evidence, likewise the greater depth to water in wells.

The communities of the Niles Cone region and those within the Alameda Creek watershed will ultimately require all of the water of Alameda Creek.

The diversion of any additional water to San Francisco from Alameda Creek must be temporary only.

A Sierra water supply is required for the San Francisco Bay region, so as to compensate the communities dependent upon the waters of Alameda Creek for the water the Spring Valley Water Company proposes to divert to the City of San Francisco and other communities.

H. A. Noble, C. E., has had charge of this work. I wish to express my appreciation of his able services, which have enabled the presentation of this report within the time allotted.

Respectfully submitted,

(S) J. H. DOCKWEILER,
Consulting Engineer.

Appendix No. 6

THE DOCTRINE OF PERCOLATING WATERS

By Percy V. Long, City Attorney.

July 31, 1912.

The following digest of and quotations from recent opinions that have a special bearing in the matter of the further or unlimited diversion of water from the Niles Cone, San Leandro, etc., has been prepared in the office of the City Attorney of San Francisco, in order to answer certain questions with reference to larger future diversion of water from near-by sources.

These declarations of principles of law regarding the use of percolating waters by the Supreme Court of the State of California remain the law of this State supported by an unbroken line of authorities to such an extent that the rule of law is fixed by these decisions in controversies between users and those who attempt diversion of percolating waters.

The Supreme Court of the State of California, in the case of Katz vs. Walkinshaw, reported in Vol. 141 of the California Reports, at pages 116 to 150, lays down the following rule, of date November 28, 1903:

> *An underground body of water* lying in an artesian belt, which does not flow in any defined stream, but is produced by percolation through saturated soil, and is pressed forward by water accumulating from ravines, canyons, and streams above, pressing down into the soil by percolation, *is not a watercourse, and is not governed by the law of riparian rights.*
>
> *Each owner of soil* lying in a belt which becomes saturated with percolating water is *entitled to a reasonable* use thereof on his own land, notwithstanding such reasonable use may interfere with water percolation in his neighbors' soil; but he has *no right to injure his neighbors by* an unreasonable diversion of the water percolating in the belt for the purpose of *sale or carriage to distant lands.*
>
> **The owners of artesian wells** sunk in an artesian belt of percolating water, the waters from which are necessary for domestic use and irrigation of their lands, on which are growing trees, vines, shrubbery and other plants of great value, **are entitled to an injunction** to restrain the diversion of the water percolating in the artesian belt, by an owner of land situated in the belt, for the purpose of conveying the same to distant lands for sale, to the irreparable injury of the plaintiffs.
>
> Where the complaint for the injunction stated in substance that plaintiffs had wells in their respective tracts, from which water flowed to the surface of the ground, which was necessary for domestic use and irrigation of their lands, and that the defendant by means of wells and excavations on her own lands drew the waters from plaintiffs' lands and conveyed them to distant lands, it states a cause of action for an injunction to restrain the diversion of percolating water; and an averment that the diversion was from an underground stream may be regarded as surplusage.
>
> *The common law rule* that percolating water, belongs unqualified to the owner of the soil, and that he has the absolute right to extract and sell it, *is not applicable to the conditions existing in a large part of this State,* where artificial irrigation is essential to agriculture, and artesian wells in percolating belts are necessarily used for that purpose.
>
> The difficulties that the courts will meet in securing persons necessarily using percolating water for irrigation by means of artesian wells from the infliction of great wrong and injustice by its diversion, if property right therein is recognized, cannot justify the court in abandoning the task as impossible. The courts can protect this particular species of property in water as effectually as water-rights of any other description.
>
> The rules respecting priority of appropriation and correlative rights in regard to the appropriation and use of percolating water include the right to appropriate any surplus not needed for use by well owners on their lands, and an equitable adjustment of disputes between overlying landowners, where the supply is insufficient for all, and proper rules relative to injunctions and the remedy at law should be applied to the solution of questions arising in the courts as to such waters.

The rule laid down in Katz vs. Walkinshaw was followed in the case of McClintock vs. Hudson, reported in Vol. 141 of the California Reports, at page 276, where the Supreme Court laid down the following rules, of date December 9, 1903:

> Under the rule established in Katz vs. Walkinshaw, ante, page 116, with respect to percolating water, it is *not lawful* for one owning land bordering on a stream to excavate in his land, *to intercept percolating water therein,* and apply it to any use other than its reasonable use upon the land from which it is taken, if he thereby diminishes the stream *to the damage of others having rights therein.*
>
> An owner of land adjoining a stream, who, by excavations in his land, takes percolating water therefrom, and to that extent diminishes the stream, has no greater rights to the water thus taken from the stream than he would have if the water were taken directly from the stream.
>
> It was the duty of the court to have found from the evidence that the taking out of the water through plaintiff's excavation and tunnel caused a diminution of the stream, and then to ascertain and state the amount of diminution.

In Cohen vs. La Canada Land, etc., Co., reported in Vol. 142 of the California Reports, at pages 439-40, the Supreme Court, in discussing this doctrine, used the following language, of date March 9, 1904:

> But since the trial of the cause in the court below, it has been definitely settled by this court in Katz vs. Walkinshaw, 141 Cal. 116, and subsequent cases, that the question whether one can maintain an action for deprivation of the use of the water by the act of another does not depend upon the fact that the deprivation was caused by the tapping or intercepting of a known stream running in a defined channel, either on the surface or underground. In such an action it is sufficient for the plaintiff to show that wrongful acts of the defendant complained of did actually deprive plaintiff of water to the use of which he was legally entitled; and if these acts consisted of sub-surface excavations it is not necessary for the plaintiff to show that a well-defined subterranean stream had been intercepted, or to show the particular subterranean conditions which were disturbed, provided it clearly appears that the acts of the defendant caused the destruction or diminution. And it has been established by these cases that the *right of an owner* of land to use water percolating therein is a right only to a reasonable use thereof for the benefit and enjoyment of his land, and subject to the maxim *Sic utere,* etc., and *does not include the right, by excavations, to diminish the flow of water to others where the*

diversion is not for a reasonable use on his own land. It would be useless to restate the principles and reasoning by which these conclusions are established; they are fully stated in both the opinions in Katz vs. Walkinshaw—the one by Temple, J. (141 Cal. 138), and the other by Shaw, J. (141 Cal. 120).

The most important case enunciating the doctrine above mentioned is the case of Miller vs. Bay Cities Water Company, reported in Vol. 157 of the California Reports, at pages 256 to 288, of date February 4, 1910. The facts involved in that case and the principles of law applied thereto are so pertinent to the present inquiry that extended extracts from the opinion of the court are copied herein. The paragraph headings and italics are added by the writer hereof, and are not found in the original opinion.

STATEMENT OF CASE.

Lorigan, J.—Plaintiff, the owner of a tract of land in Santa Clara County upon which was planted an orchard of twenty-one acres of deciduous trees, brought this action against the defendant, a California corporation, organized for the purpose of furnishing water to cities and their inhabitants, and against certain of its officers, to enjoin the diversion by them of any waters of the Coyote River in said county; either those waters flowing on the surface of the bed of said river or flowing or percolating underneath it, or from diverting any of said waters to any extent.

As the basis of his right to an injunction it was alleged in the complaint, among other things, that beneath the land of plaintiff and under a stratum of impervious clay there is a stratum of gravel always full of water under pressure, which water was constantly supplied to said stratum from the sinking and sub-surface flow of the Coyote River; that from a well sunk in the said water-bearing stratum plaintiff had for years annually irrigated his orchard which was of great value; that if defendants were permitted to divert the waters of the Coyote River, as they threatened to do, above or at a certain gorge known as the "lower gorge" of the river, the gravel stratum of plaintiff and his well would be deprived of water from which to irrigate his orchard and the orchard would be irreparably damaged and soon become of little or no value. The answer denied all the material allegations of the complaint, and particularly denied the existence of any gravel stratum under the land of plaintiff, connected with or supplied from the waters of the Coyote River, and further denied that defendants intended to divert any surface or sub-surface waters of the river or any waters at or above said lower gorge except a large portion of the waters of the river which sunk at that point and became impounded and stored in the gravels deposited therein and did not flow at all, and except, further, that they intended to divert "a portion of the storm or flood waters which for a short period in every year rush in great volume and with great velocity down the channel of said river to the bay of San Francisco and are wasted and lost therein."

Plaintiff had a decree as prayed for and defendants appeal therefrom and also from an order denying their motion for a new trial.

FINDINGS OF FACT BY THE TRIAL COURT—STRATUM OF GRAVEL UNDERLYING SANTA CLARA VALLEY.

Upon the issues presented under the pleadings the trial court found the following facts: That underneath the surface of the land of plaintiff known as the "Miller Ranch," which is about four miles northerly from what is known as the lower gorge of the Coyote River, and underneath a stratum of impervious clay there is a stratum of coarse, loose gravel seven feet thick, being from eighty-three feet to ninety feet below such surface, which is always full of water, under pressure, the same being constantly supplied to said stratum of gravel from the sinking and sub-surface flow of the waters of the Coyote River, as hereinafter stated. Said stratum of gravel extends from plaintiff's land southerly and approaches the surface of the ground and connects with, and is a part of, the gravel bed of the Coyote River, just below and in said lower gorge of said river. *The plaintiff for years past has had a well on said land extendng down into said stratum of gravel, through which he has pumped the water therefrom upon his land, and irrigated his orchard,* and, if unable to do so, his orchard and land will be irreparably injured.

DESCRIPTION OF COYOTE RIVER AND WATER SUPPLY THEREFROM TO GRAVEL STRATA AND ARTESIAN WELLS.

The Coyote River rises to the eastward of the Santa Clara Valley, in that portion of the Coast Range Mountains known as the Mount Hamilton Range. It is formed by the union of a number of smaller streams which rise and have their confluence south of Mt. Hamilton, and thence issues in the single stream of the Coyote River into the Santa Clara Valley, through a narrow gorge, known as the "upper gorge," about twenty miles south of the city of San Jose, and thence flows northerly along the eastern edge of the Santa Clara Valley about eight miles to the point where the valley narrows to what is known as the "lower gorge," which lies about twelve miles south of the city of San Jose. The channel of the river passes through this lower gorge and extends thence northward about twenty miles to the San Francisco Bay. The Coyote River has a watershed in that portion of the Mount Hamilton Range wherein it rises over two hundred square miles, and supplies by far the greater portion of the underground or artesian waters of all that part of the Santa Clara Valley which lies northerly of the lower gorge, and all the rain falling upon the watershed drains into the Coyote River before it enters the Santa Clara Valley at the upper gorge. During a few days in times of freshets or high waters, much of the waters of said river run in its bed from the upper gorge to the bay of San Francisco; but during some seasons freshets or high waters occur only to a limited extent, and in other seasons they do not occur at all; and at all times, whether they do or do not occur, a large portion of the waters of the river and, during the rainless months, substantially all thereof, sinks into said gravel stratum during its course to at least as far northerly as the city of San Jose, and flows or percolates through the said gravel stratum and other gravel strata connected therewith, from and just below said lower gorge, to at least as far northerly as the bay of San Francisco. Said waters keep said gravel stratum, and said other gravel strata connected therewith, full of water and under pressure, and the same rise up in plaintiff's said well from fifty-five to sixty-three feet above said stratum, the variation depending mainly upon the time of the year, and also upon the flow of water in the river; and said waters rise up in all the other wells which have been bored down to the said gravel strata connecting therewith. Between San Jose and the bay of San Francisco, such pressure causes the water in said gravel stratum and the gravel strata connecting therewith to actually overflow from the wells connected therewith in large quantities, making what is usually designated "*flowing artesian wells.*" The largest of said flowing artesian wells are those nearest the bay of San Francisco, the waters in said gravel stratum and gravel strata connecting therewith, which furnish water for said last-named wells, being at a lower level below the level of said gorge and under greater pressure from said waters so sinking in said stratum at said gorge than are the waters in said gravel stratum and strata at points further south from said bay of San Francisco. At the lower gorge, Santa Clara Valley is only about four hundred yards wide, and consists almost entirely of the gravel bed of the Coyote River; and said gravel bed of said river there extends through the lower gorge between the hills at that point, and extends down to the bedrock, lying from thirty-five to one hundred and sixty-five feet below the surface of the gravel through such gorge; and on the surface of the gravel bed of said river, or underneath through the gravel bed thereof, all the waters of said river and of said watershed flow and percolate in a northerly direction; and all of said waters flowed or percolated through said gravel bed, underneath the surface thereof, at the date of commencing this action.

ATTEMPT OF DEFENDANT TO DIVERT WATER OF COYOTE RIVER FOR COMMERCIAL SALE, THEREBY DEPRIVING PLAINTIFF'S WELL OF SUB-SURFACE PERCOLATING WATER.

It is further found that at the time this action was commenced—January 9, 1904—defendant had sunk a shaft in the gravel bed of the Coyote River at the lower gorge and was then installing powerful machinery and pumps and intended therewith and by other means to divert substantially all of the surface and sub-surface water of the river amounting to some twenty million gallons per day or more, prevent these waters from passing over said lower gorge northward, and carry them by pipes and other means from said point of diversion to other points and sell the same as an article of merchandise, thus preventing them from returning to the river and supplying water to the gravel stratum in the land of plaintiff, which stratum, if they were so diverted by defendants, would be without sufficient water to enable plaintiff to irrigate his orchard or land; that defendant corporation also intended to divert during a portion of each year a large portion of the surface waters of the Coyote River at points on the river before and after it emerged from the Mount Hamilton Range at the upper gorge and above said lower gorge and divert the same to other points for sale and prevent any portion of the water from returning to the river or gravel bed thereof, and, generally, that the defendant corporation unless restrained threatened to divert and carry the waters of the river beyond their own lands for sale as merchandise, prevent them from returning to the river or gravel bed, with the result that any or all of these threatened and intended diversions would prevent these waters from flowing or percolating into the gravel stratum northerly of the lower gorge, and prevent plaintiff from having any water in his well with which to irrigate his orchard, and so cause irreparable damage to the same. Continuing, it is found that no material part of the waters underneath the land of plaintiff are supplied from any source other than the waters which fall upon the watershed of the Coyote River. The point where said river emerges at the upper gorge from said range of mountains into the side of the Santa Clara Valley is about eight miles southeast from said lower gorge, and is over one hundred feet higher than the lower gorge. Between these two points is that portion of said valley which is designated by the defendants in their answer as being known as the "Coyote Valley." This Coyote Valley has therein very large strata of gravel, extending and descending continuously from the bed of the river at the upper gorge to the gravel in the river at the lower gorge. At the lower gorge the gravel extends from surface to bedrock, which, at its deepest point, is one hundred and sixty-five feet deep. Through these gravels at the lower gorge flow about twenty million gallons per day, a little more in the wet part of the year and a little less in the dry part of the year. The flow is supplied mainly from the said gravels of said "Coyote Valley;" and those gravels are in turn constantly, but chiefly in the wet part of the year, supplied by the waters of said river after it emerges into said valley at the upper gorge. The waters of these very large strata of gravel in said "Coyote Valley" slowly flow northward to said lower gorge, and through the same, and on down toward the bay, through said underground gravel strata, north of said lower gorge; and would soon, within two years at most, all flow through said gravels in said lower gorge, if they should receive no further supply from said river. No water is stored or impounded in the said gravels in said "Coyote Valley;" but though said gravels impede the flow of the water therein, it flows constantly and continuously through them and through the gravels in said lower gorge and thence through said gravel strata north of said gorge. *The defendants threatened and intended to build a dam across said lower gorge, with the bottom resting on bedrock, and extending to the surface of the gravel. This dam, if built, would effectually prevent any of the waters heretofore flowing through said gravels of said gorge from thereafter flowing or passing through the same.* If defendants pump and extract no more water out of the gravels of said gorge than their present shafts, tunnels, pumps, and appliances now permit, still, if such amount of water as could now thereby be pumped were pumped, *the plane of the waters in the gravels below said gorge would be thereby lowered to such an extent that the same would be entirely below the bottom of said gravel stratum in plaintiff's lands, and plaintiff's said well would be thereby deprived of water.* Soon after heavy rains upon the watershed of the river, portions of the storm or flood waters of the river flow in its channel to the bay, for short periods of a few hours to a few days—the lengths of the periods being dependent upon the heaviness of the rainfall. Large portions of the storm waters flowing in the channel of the river sink into the gravel strata in and along the bed and banks of the channel. The volume of the storm waters flowing in the channel decreases, from a point, near the upper gorge, to a point near the northern limits of San Jose; and from the latter point to the bay the volume of the waters increases in case of very heavy rains or of frequent heavy rains during any winter. A larger volume of storm waters sinks in the gravel strata in and along that part of the channel at or near the lower gorge, of the length of about two miles, than in the gravel strata in and along any other part of the channel. The waters, sinking into such gravel strata, flow and percolate into the several gravel strata underlying the surface of the Santa Clara Valley, and among others the stratum penetrated by the plaintiff's well. The storm waters coming from a very heavy rain, or from frequent heavy rains during the winter, largely increase the flow and percolation of water into the gravel strata underlying the valley, and thereby the water in such strata and the pressure of the water therein are increased, and the water in the wells, including the plaintiff's well, rises, and wells are caused to flow, and flowing wells to increase their flow. Such increase of water, of its pressure, of its rise in and flow from the wells, is proportionate to the volume of storm waters flowing in the channel of the river.

DIVERSION OF STORM WATERS WILL DEPRIVE VALLEY OF IRRIGATION.

In addition the court found that from the evidence presented in the case it could not "determine with certainty what portion of the storm waters issuing from the upper gorge during any rainy season, or during any rainstorm, sinks into the gravel strata underlying the valley; but more than one-third of the storm waters flowing during the last six years did so sink. Should those storm waters be prevented from flowing in the channel of the river below the upper gorge, and be diverted to places not within the valley, the gravel strata underlying the valley would be deprived of their usual supply of water, and within a short time—not more than two years—the wells penetrating those strata would not yield enough water for profitable or successful irrigation, and would not yield more water than the surface wells."

DEFENDANT ENJOINED FROM ARRESTING OR OBSTRUCTING FLOW OF RIVER.

The decree entered perpetually enjoined the defendant corporation and its officers from arresting or obstructing at or above the lower gorge (except for the reasonable use thereof on the lands of the said corporation in the exercise of its riparian rights) any of the water of the Coyote River which, excepting for said arresting or diverting, would flow on the surface of the bed of said river through said gorge, or would flow or percolate through said gorge underneath the surface thereof. * * *

DESCRIPTION OF SUBTERRANEAN CHANNELS UNDERLYING SANTA CLARA VALLEY.

There can be no doubt but that it was as clearly proven under the evidence as such matters can be proven that there are underlying a vast territory in the Santa Clara Valley—some twenty miles square—numerous channels created by the Coyote River through its action in ages past when, in the building up and forming of the valley, its waters rushed in enormous quantities from the mountains, changing from one side of the valley to the other, and constantly varying its course in its flow through the lower gorge northward toward the bay of San Francisco. These old channels now lie beneath the surface of the valley at varying depths; channels beside channels, and channels crossing and interconnecting with each other, through each of which the Coyote River once flowed in its open course, but which are now underground channels filled with loose and coarse gravel, through which waters still flow, supplied to them through percolations from the Coyote River, with which these old gravel channels have always been connected, and that the particular underground channel or gravel stratum from which the well of plaintiff is supplied constitutes one of these old channels, which is likewise connected with and supplied from the waters of Coyote River. The intake of all these old channels, including that from which the plaintiff derives his water, is in the enormous bed of gravel extending several miles northerly below the lower gorge. For at least one mile below the lower gorge this deposit consists of pure gravel from surface to bedrock.

CHANNELS FED BY STORM WATERS OF COYOTE RIVER.

Into this vast gravel bed during the winter and spring when the storm waters gather between the upper and lower gorge and discharge themselves through the latter, there sink into these gravels immense quantities of water, in amount limited only by the extent of the rainfall, but in any season of flood extending largely into hundreds of millions of gallons per day, the evidence showing when tests were made that these intakes amounted in some seasons to from three hundred to five hundred million gallons a day during a single storm. It is quite clear that these quantities of waters sink into the gravels and fill up the various branch channels underlying the valley which connect with these gravels by the pressure of the storm waters passing over them, and the supply of these underground channels is obtained in no other way; and it is equally clear that the intake into these gravel beds and the gravel strata along the flow of the river generally is in proportion to the height and breadth of the storm waters passing over them and the consequent pressure they exert to increase the percolation of the waters in the vast gravel bed and gravel strata. *That the waters which lie in these old branch channels are supplied by the percolation of waters into the gravel beds and strata from the storm waters of the Coyote River is beyond question from the evidence, as it equally appears that the flow of these storm waters during the recurring heavy rains is absolutely necessary* *to sustain the supply of water thereto which would otherwise and in a few years be exhausted.* That these underground strata are connected with the river in these gravel beds at the lower gorge and that their waters are thus supplied to these branch underground channels therefrom and that the findings of the court to that effect are true appears not only from the evidence of the geological expert—Dr. Branner, whose qualification to testify on the subject was conceded, and who testified to the effect—but also from tests made in wells and the testimony of well-borers and well-owners owning lands over these gravel strata, and others speaking on the subject. Of course this supply from the rainfall and storm waters is augmented by the twenty million gallons which year in and year out daily percolate over the gorge and which is designated as the normal flow of the river, but it is quite evident that this quantity of itself, and save for the immense quantities which are supplied by the annual storm waters, would not sufficiently meet the needs of those hundreds of property owners whose lands are situated above the various old branch channels, all having their intake into the gravel beds at the lower gorge, and who draw water for their irrigation from wells sunk in these various water-bearing gravel strata. While it is true that this controversy concerns only the plaintiff and defendants and must be disposed of by a consideration of their respective rights, yet, as bearing upon the correctness of the findings of the court as to the source of supply of these waters of plaintiff we have a right to take into consideration the evidence which shows that these various water channels underlying square miles of territory in the Santa Clara Valley all have their intake and ramify from the vast gravel beds extending for miles northerly from the lower gorge; that in instances they connect with each other and that all are affected by the flow of the flood waters in proportion to their volume over the vast gravel beds which serve as an intake for them and supply the various underground branch streams over which these lands are situated. The tests which were made, as well as the evidence of these various well-owners showing that the water in the hundreds of wells in the district in which lands overlie these various channels decreases in depth in the summer time while the irrigation season is active and increases in volume in the winter rains and flood waters and increases in proportion as these floods are frequent and heavy or less frequent or light, and that this was the effect in all wells, including those situated on the channel in which Miller's well was situated, was sufficient of itself to warrant the finding of the court as to the sources from which the waters in the strata underneath Miller's land were supplied. * * *

RIGHT OF OWNER OF LAND HAVING AN UNDERGROUND WATER SUPPLY TO THE ACCUSTOMED FLOW IS PARAMOUNT TO THAT OF AN APPROPRIATOR, TO THE EXTENT NECESSARY TO BRING THE WATER BEARING STRATUM UP TO ITS FULL CAPACITY.

Now, as to the claim that the court failed to find upon material issues raised by the answer of defendants, namely, that they did not intend to divert any portion of the surface waters of the Coyote River "except or other than a portion of the storm or flood waters which, for a very short period in every year, rushed in great volumes and with great velocity down the channel of said river to the bay of San Francisco and are wasted and lost therein."

It is not clear from this averment what is meant by "storm" or "flood waters wasted and lost in the bay." It is not a clear allegation that they were anywhere lost and wasted in the river, which of course is where the appellants intended to divert them. But assuming that it was; that, in effect, it amounted to an averment that the waters which appellants intended, and which they claimed a right to divert, were the storm waters which were lost and wasted at the point of diversion because they could serve no useful purpose in their flow through the lower gorge to the bay of San Francisco, still there was no evidence introduced by the appellants to support this allegation. **The owner of land having an underground water bearing stratum supplied by the flood waters of a stream has a primary right to the full flow of such waters, in order to bring his stratum up to its water-bearing capacity.** In torrential streams, such as the Coyote River, floods vary in extent with different seasons and in different years and those of one season or one year may be insufficient to supply the underground stratum connected with the stream, while those of another season or year may be more than sufficient. While the owner of the underground stratum is only entitled to the flow of the flood waters to the extent that they may replenish his water-bearing stratum, **still his right to the accustomed flood flow of the stream for that purpose is paramount to that of the right of an appropriator to divert any of the waters for use beyond the watershed. If the accustomed flow is more than necessary to supply the underground stratum, the burden of proof is upon the appropriator seeking to appropriate the surplus to show that there is a surplus.** In the case at bar the burden of proof was upon the defendants setting up a claim to an alleged portion or surplus of flood waters upon the ground that such waters were wasted or lost waters to prove that fact. In the absence of such proof, a finding on the averment was not necessary. Senter vs. Senter, 70 Cal. 619, 11 Pac. 782; Murphy vs. Bennett, 68 Cal. 528, 9 Pac. 738; Gregory vs. Gregory, 102 Cal. 52, 36 Pac. 364.)

Aside from this, however, if it was intended to allege that a portion of these storm waters were wasted and lost waters at the point of intended diversion, the court found that they were not in those findings which we have recited, to the effect that the storm waters after passing the lower gorge sunk into the vast gravel beds below it and flowed into the several strata underlying the surface of the Santa Clara Valley and among others the stratum penetrated by the well of plaintiff; that the pressure of these storm waters largely increased the flow and percolation of water into the said underlying strata and that "such increase of water, of its pressure, of its rise into and flow from the wells, is proportionate to the volume of the storm waters flowing in the channel of the river," and that if defendants should divert a portion of said waters at the gorge, or at other places above the gorge, plaintiff would be prevented from having enough water in said gravel stratum underneath his land to irrigate his orchard or any considerable part thereof.

These are clear findings that there was no "waste or loss" of the storm waters until, at least, they had served the essential and necessary purpose of supplying to plaintiff their force and volume in forcing such supply into the vast gravel beds in which the various underlying strata referred to had their intakes and had flowed over these gravels on their way to the bay.

Nor can there be any ground of complaint that the court did not make any finding as to the exact amount of flood waters of the Coyote River which sunk and became part of the waters underlying the lands of plaintiff, or as to the exact amount of flood waters which did not sink but passed over the gravel beds in which these underlying strata had their intakes and were wasted and lost in the bay of San Francisco. There was no issue as to any amount or exact proportion of these waters which sunk or did not sink, the defendants asserting simply a right to divert at or near the lower gorge a portion of the storm waters which rushed down the channel of the river to the bay, and, as they alleged, became lost and wasted therein.

The complaint alleged that defendants were threatening and intending to divert and carry away "the waters of said Coyote River" beyond their own lands and prevent the same from ever returning to the river or flowing through the gravel within the gorge and supplying the gravel stratum in which the plaintiff's well was sunk, thereby depriving him of waters to irrigate his land and so irreparably damaging his land and orchard. This allegation that they were threatening and intending to take "the waters" of the river was, in effect, an allegation that they intended to divert all the waters thereof. The court on sufficient evidence, as we have already shown, found all these particular allegations of the complaint to be true and was a full finding of the quantity of storm waters which the defendant intended to take—namely, all of them, even if it be assumed that an issue were made on the matter of quantity. * * *

Having disposed of (as far as we deem consideration necessary) the attack on the findings and the claim of alleged want of findings, and being satisfied that there is no merit in the points made relative thereto, we come now to a consideration of the legal principles involved on the appeal.

APPELLANTS' CONTENTIONS.

It is insisted by the appellants: (1) That as the plaintiff is a non-riparian owner he has no right to enjoin to any extent the diversion of the waters of the stream by an appropriator, on the ground that the stream contributes percolating waters to his non-riparian lands; and (2) even if he has, the court was not warranted in enjoining the defendants, as appropriators, from appropriating the flood waters of the Coyote River which they claim waste themselves in the bay, in order that another portion of the flood waters may continue to sink into the sub-surface gravels and supply percolating waters to his non-riparian lands.

CLAIM THAT RIGHTS OF APPROPRIATOR ARE SUPERIOR TO THOSE OF OWNERS OF SUPERIMPOSED LANDS DISALLOWED.

As an abstract proposition of law, applied to the concrete facts in this case, the contention of appellants is that, notwithstanding it is clearly established that the waters, surface and sub-surface, which either flow or percolate through the channel of the Coyote River, at or above the lower gorge, pass through well defined artesian gravel strata in the Santa Clara Valley connected with the stream itself, and furnish a supply of water for irrigation to a territory to which its use is essential, still that territory can be deprived of this inestimable benefit by an appropriator seeking to divert all the waters of the river away from the stream as a commercial proposition, thus rendering the lands overlying the various artesian strata valueless, and that owners of these superimposed lands have no rights which are invaded, and hence, no right to apply for an injunction to restrain such a diversion.

RULE OF COMMON LAW DOES NOT PREVAIL IN CALIFORNIA.

The principal stress of the argument of appellants against the right of plaintiff to restrain their diversion of the waters flowing through the lower gorge and percolating into the subterranean stratum under the land of plaintiff, is based on the claim that plaintiff is not an owner of land riparian to the stream, who would be entitled to a flow of its waters, but is simply an owner of land situated above percolating waters supplied in part by percolation from the stream, who has no rights against an appropriator. This is, in effect, a contention that the rule at common law applicable to percolating waters, which gave an owner of land all that lay beneath it with a right to interrupt and take away waters passing to his neighbors' wells—the doctrine of *cujus est solum*—governs the respective rights of plaintiff and defendants. But whatever the extent to which that doctrine may have heretofore obtained in this State, at least ever since the decision in Katz vs. Walkinshaw, 141 Cal. 116 (99 Am. St. Rep. 35, 70 Pac. 663, 74 Pac. 766), it has been modified by the application of the more reasonable doctrine of *sic utere tuo* as to percolating waters.

CONDITIONS IN CALIFORNIA WHICH COMPEL A CONTRARY RULE.

It would be a waste of time to particularly discuss the reasons which impelled the modification of the common-law doctrine of an absolute right in each landholder (and as an appropriator the appellants insist upon this right) to abstract all percolating waters under his land and dispose of them as he saw fit, without regard to what extent he might deplete these waters under the land of his neighbors. The climatic conditions of this State, the great stretches of arid and semi-arid lands, the uncertainty of the seasons and varying rainfall, the necessity of irrigation and the vast superiority of underground waters as a steady and ready means of irrigation over the uncertainty of a similar supply from a surface stream which, in many instances, becomes dry at the very time when irrigation is necessary; the vast areas of land brought under cultivation and production by irrigation and additional areas still to be improved by it; the enormous draft which this constant improvement and cultivation makes on a supply which is limited and which will become inadequate for all as population increases and additional lands are to be brought under cultivation and improved by irrigation; these, and many other causes, impelled a departure from the old doctrine and a limitation of it and the adoption of the just principle that a common and essential necessity—water—when supplied to well-defined strata from whatever source should be preserved to lands overlying them for reasonable use upon them.

CALIFORNIA RULE AND AUTHORITIES RESTATED.

In Katz vs. Walkinshaw, 141 Cal. 116 (99 Am. St. Rep. 35, 70 Pac. 663, 74 Pac. 766), in the opinion written by the late Justice Temple and in that written by Justice Shaw upon a rehearing (granted for further argument) the necessity for modification of the *cujus est solum* doctrine as inapplicable to the conditions in this State was fully discussed, announced and applied. In that case the defendant had sunk wells in the same artesian belt underlying the lands of plaintiff and in which his irrigation wells were sunk and was diverting the water for sale to lands distant from the saturated belt from which the artesian waters were derived. Defendant asserted there, like appellants as appropriators do now, that as these were percolating waters he had under the common-law rule to which we have just adverted, an absolute right to abstract them to any extent he saw fit and to use them anywhere he pleased, notwithstanding it would result in depriving the well of plaintiff of any supply for irrigation. The common-law rule was rejected as inapplicable to the conditions in this State and the rule of *sic utere tuo* announced, and applying it, it was held that the rights of the parties in the suit to take these particular waters were correlative and that the defendant could not divert them for sale elsewhere so as to prevent plaintiff from obtaining a reasonable supply for irrigation and other ordinary uses upon his land. The doctrine thus announced in this pioneer case has been subsequently followed so that the rule is now settled beyond further question. (See McClintock vs. Hudson, 141 Cal. 281, 74 Pac. 849; Cohen vs. La Canada, etc., Co., 142 Cal. 437, 76 Pac. 47; Montecito, etc., Co. vs. Santa Barbara, 144 Cal. 584, 77 Pac. 1113; Verdugo Canon Water Co. vs. Verdugo, 152 Cal. 655, 93 Pac. 1021; Burr vs. Maclay, 154 Cal. 439, 98 Pac. 260; Hudson vs. Dailey, 156 Cal. 617, 105 Pac. 748.) * * *

STORM WATERS ARE NOT WASTE WATERS SUBJECT TO APPROPRIATION, AS LONG AS THEY CAN PERFORM A USEFUL SERVICE.

But it is quite obvious that merely because waters are flood or storm waters of a stream—that is, on account of unusual rains the waters of a stream are increased beyond the normal flow—that these flood or storm waters are not, therefore, surplus waters of the stream which serve no useful purpose and are subject to appropriation. What are called the storm waters of the Coyote River are not waters which are precipitated over the lower gorge only in occasional seasons. They are generally of annual occurrence and flow at great height and breadth over the deep porous gravel beds below the lower gorge, although they last but a short time. They are confined to the general channel of the stream as the banks of the Coyote River are of great height, in some places as high as thirty-eight feet, and within the memory of man, no overflow of the river until it gets to the low land near the bay, has ever been known. But even if these storms are of short duration and the waters are precipitated with great rapidity into the bay, they cannot be said for that reason alone to be waste waters or subject to appropriation. *They are only waste waters and capable of appropriation as such if they serve no useful purpose as storm waters.* But in the case at bar there can be no question but that the flood waters perform not only a useful but an indispensable service in pressing into the gravel beds or trough at the lower gorge by their great breadth and enormous weight a large portion of the waters which go to supply the various artesian strata, including that of plaintiff which have their intake therein. The extent to which these waters sink into these gravels below that gorge depends upon and is proportioned to the pressure exerted by the breadth and volume of the storm waters. The sub-surface flow of twenty million gallons per day does not keep up the supply, and that supply is augmented and is only partially kept up by the waters which are forced into the gravels at the lower gorge by the pressure of the flood waters. There are some years when there are no flood waters at all and years when such floods as come are comparatively small, and there are also dry years occasioned through less than the ordinary rainfall. In every year when there are no floods and in every dry year the waters in these gravels suffer additional depletion on account of the extent of the drafts for irrigation which are necessarily made upon them to meet the deficiency in the rainfall, and this depletion is only partly restored by the flood waters of subsequent years.

LOWERING OF WATER PLANE.

The water plane in these gravels, and consequently in the various strata to which it is supplied is, as the evidence shows, gradually lowering. Neither the gravels nor these underground strata have been completely filled since a season of unusual rains in the years 1861-62, when the flood waters brought them up to their full water-bearing capacity, and, hence, there was a surplus of flood waters which may be said to have served no useful purpose and were wasted in the bay. Since then on account of the increase of population and the improvement of the valley, the high state of cultivation to which lands have been and are being brought on account of their susceptibility to irrigation from these underground artesian strata and the consequent vast drafts made by the increasing number of wells sunk therein, the water plane by continuous and extensive irrigation during the summer seasons has been and is yearly gradually being lowered so that the flood waters, even to the extent to which they contribute of themselves to replenish the supply and under the pressure of their breadth and volume effect it, still do not bring these artesian strata up to near their full capacity. And the extent to which these artesian strata are now supplied, which is less than their full capacity, and which must be still further depleted as additional lands are brought into cultivation and irrigation from wells sunk into them is, in addition to this daily supply of twenty million gallons always flowing through the lower gorge, derived solely from the storm waters and is supplied in proportion to their breadth and volume. It is quite obvious that as the storm waters flowing over the gravels of the lower gorge do not, even under their enormous pressure, now bring the various artesian strata having their intake therein up to their full capacity, and in the nature of things must be further depleted as additional well drafts are made upon it, to permit them to be diverted at or near the lower gorge must inevitably deprive the various gravel strata, including that of plaintiff, of their usual water supply, and as the court found, these strata within a few years would not yield enough water for profitable or successful irrigation, nor yield more water than the surface wells. *As it appears, therefore, that all these flood waters, either by partially sinking into the gravels, or by their breadth and weight causing an increased surface sinking, are inadequate to fully supply the underground waters in these artesian strata, it is quite clear that it cannot be said that any portion of them are waste or lost waters which the appellants are entitled to divert from the stream above the lower gorge.* All these waters are necessary of themselves or by their force to supply the underground waters which they, even now, fail to do to the full capacity of the underlying strata, *to which full capacity the plaintiff and others interested in them are entitled.* Performing this necessary and indispensable service which could not be supplied without them, no part of them can be said to be waste waters until they have performed it as far as they are capable of doing so, and have passed over the gravels on their way to the bay. This seems to be so plain as to require no further particular discussion. If at any time these flood waters, or any portion of them, can be characterized as waste waters in their flow from the upper gorge towards the bay, it certainly is not while they are in the river above the lower gorge where appellants desire to divert them. If they become waste waters it is only after they have passed the gravels at the lower gorge and have performed the necessary and useful purpose of supplying them and the artesian strata connected with them, as far as they are capable of doing so, and from there are rushing toward the bay. We are not prepared to say that, even in their flow after passing the gravels in which the intake to these artesian strata lie, they serve no other useful purpose, but certainly these storm waters do not become waste until they have flowed over these gravel beds and are on their way to the bay. It is only there that it may be said that they can perform no further useful service; the only place where they first become waste waters and where, without apparently invading the rights of anyone, they may be diverted. No reasonable objection could be made to the diversion of the waters by the appellants there because they are then, for all practical purposes, waste waters. But it is quite clear that this is the only point on the stream where it can be said, as far as plaintiff is concerned, that they are waste waters.

Appendix No. 7

THE INADEQUATE WATER SUPPLY NOW FURNISHED PARTS OF SAN FRANCISCO BY THE SPRING VALLEY WATER COMPANY

From Information on File at City Hall, with Illustrative Notes and Photographs by HARRY A. NOBLE, C. E.

In the preceding report, and in the appeal by the Mayor and others for an immediate offer of sale of the water works to the municipality, it has been stated that parts of the city are suffering from an inadequate water supply. The following examples are offered in proof of this inadequacy, and their number could be increased indefinitely.

The preceding map has been prepared to show the present distribution of the water of the Spring Valley Water Company's system. As indicated by the hatching on the map, the system may be divided into four service zones or areas, namely, the Low, Middle, High and Hill Services. The topography of the city requires such a distribution of the water supplied from reservoirs located at different elevations. Those areas having no water service at the present time show on the map without hatching.

Regarding Inadequate Water Service In Various Sections of the City

A large number of complaints have been filed by various householders and improvement clubs regarding inadequate water mains and want of fire protection in their respective districts. Abstracts of a few of these complaints are given in the following tabulation, numbered consecutively and segregated into districts for convenience of reference. On the preceding map the complaints are located by their respective numbers.

Photographs have been taken to show the residences in the vicinity of some of the complaints.

It will be seen that most of these complaints against the Spring Valley Water Company are located in the outlying Richmond, Sunset and Ocean View districts, having no large water mains in their vicinity. *These sections are rapidly building up with small residences, and now require additional water service.*

The complaints from the Buena Vista, Bernal Heights and Fairmount districts are from well built-up sections which receive their water from the high service supply. The mains in these sections have become inadequate, and the small tanks which serve as reservoirs are utterly insufficient for a proper reserve for fire or other emergencies.

The complaints from the Western Addition are located in the center of the main residence section of the city where adequate mains should exist to give sufficient water supply and fire protection.

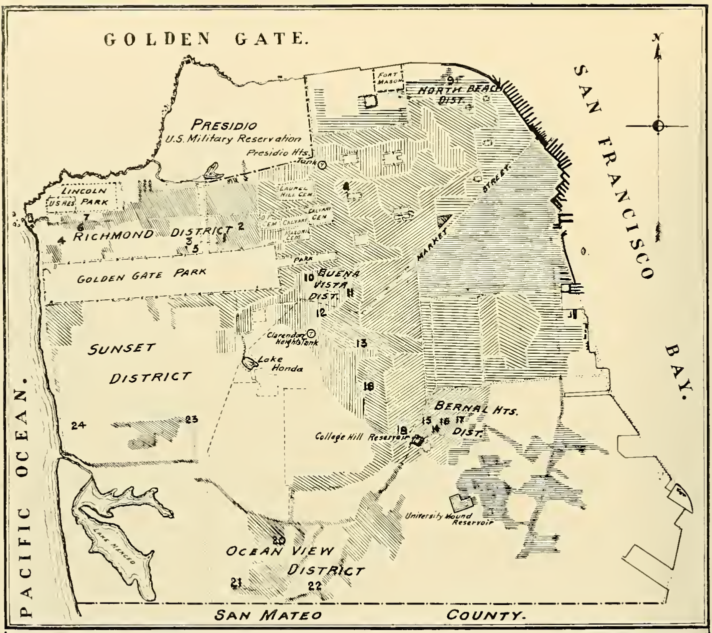
Several large manufacturing plants are located in the vicinity of the complaint received from the North Beach District which should have adequate fire protection. The high pressure fire system now being installed by the city in this vicinity will relieve this situation, but in all other cities of the country the water works are expected to give a supply suitable for fire service in all ordinary cases.

Investigation in Progress By City Engineer's Office

A thorough investigation is being carried on at the present time in order to determine the sections of the city served by inadequate mains, and the best means to remedy the existing conditions. The location and size of the existing mains of the Spring Valley Water Company are also being investigated to see what facilities are at hand to meet the requirements of those districts that are not receiving an adequate water supply. This work is progressing as rapidly as possible, and a report is expected and changes are proposed by which in the near future the various outlying districts, such as the Richmond and Sunset, will receive sufficient water to meet the present as well as the future requirements.

Assistant City Engineer Ransom, as a result of this investigation, proposes a main of sufficient size for the Richmond District so that its present lack of supply in certain sections, as well as in those sections which are not now served with water, will be taken care of. Likewise, he proposes that the Sunset District be supplied with a suitable main, and a request is to be made that all other districts requiring additional water supply be taken care of in like manner, but meanwhile the suffering goes on as evidenced by the following.

Appended hereto will be found copies of reports of the Chief Engineer of the San Francisco Fire Department relative to the present lack of suitable water mains and inadequate fire protection in different sections of the city; and also a list furnished by the City Engineer, giving the streets on which there are no Spring Valley mains for fire protection.



Showing Present Distribution of Water Spring Valley Water Co's System

Low Service Area — University Mound Reservoir	▤
Middle Service Area — College Hill Reservoir	▨
High Service Area — Lake Honda	▧
Hill Service Area — {Clarendon Heights Tank Presidio Heights Tank	▥
S.V.W. Co's pipe mains supplying outlying districts	▨
Distributing Reservoirs shown thus	▭
Public Parks shown thus	⬚
Location of Complaints regarding inadequate water service	1, 2, 3, 4, 5, etc.
Blank Areas are not supplied	

0 1 2 3 4 5 Miles

ABSTRACTS OF A FEW OF THE COMPLAINTS MADE BY VARIOUS HOUSEHOLDERS AND IMPROVEMENT CLUBS REGARDING INADEQUATE WATER SERVICE OF SPRING VALLEY WATER COMPANY FILED WITH THE BOARD OF SUPERVISORS OF SAN FRANCISCO.

Richmond District

(See map for locality of complaints.)

Locality No. 1. *Park-Richmand Impravement Club.*—Dated August 7, 1911. Located in vicinity of Eleventh and Twelfth Avenues, Balboa and Anza Streets.

Camplaint of Mr. Bacheldor, 1111 Balboa Street (B Street). Only a 1½-inch main in the street; impossible to get water in second story during the time of day when water is used freely. Stated that Spring Valley Water Company flatly refuses to put in larger mains.

Camplaint of J. B. Glutz, west side of Eleventh Avenue, between Anza and Balboa Streets. New building, and Spring Valley Water Company insisted that Mr. Glutz put in his own service pipe. The people across the street have water from a 2-inch main installed by themselves. This entire block, which on one side is built up with nice homes, is getting its service from a 2-inch pipe.

Also, a communication from Board of Fire Commissioners states in regard to installation of fire hydrant at Twelfth Avenue and Balboa Street: "Impossible to install hydrant at this location for reason that there are no water mains of sufficient size."

EAST SIDE OF ELEVENTH AVENUE, FROM BALBOA STREET TO ANZA STREET, TAKEN FROM CORNER OF BALBOA STREET.

A district with inadequate water pressure. A 2-inch main supplies the residences in this block.

Locality No. 2. *M. L. Grassman.*—Dated May 22, 1912. Located at 525 C Street, between Sixth and Seventh Avenues.

Complaint: Regarding lack of water service. Says Spring Valley Water Company refused him water service for his new house at 525 C Street, unless he put in his own main, 152 feet in length, and in addition pay them $10.00 for the connection. Mr. Grossman was obliged to do this in order to get water into his house.

Locality No. 3. *Variaus Householders.*—Dated June 22, 1912. Located in Richmond District, bounded by Fifteenth Avenue on east, Geary Street on north, Nineteenth Avenue on west, and Fulton Street on the south.

Camplaint: In this district there are no water mains of sufficient size to supply water for fire protection or for domestic use. In some streets there are no mains whatever. For six years past the greater part of this district has been inadequately supplied with water. In order to get any water for domestic purposes during the day it is necessary for residents to draw water early in the morning before 8 o'clock, as after that time the supply has been shut off almost entirely until 9 o'clock in the evening. This has retarded building up of the district. A large number of property owners have delayed erecting residences until an adequate water service is secured.

SEVENTEENTH AVENUE, LOOKING NORTH FROM FULTON STREET.

A district rapidly building up, but not having adequate water mains for fire protection or for domestic use.
Seventeenth Avenue is now being paved with asphalt.

LOOKING NORTHEAST FROM CORNER OF NINETEENTH AVENUE AND FULTON STREET.

Nineteenth Avenue, in the foreground, is paved with asphalt. This photograph shows a portion of same district as shown above.

Locality No. 4. *Sutro Heights Improvement Club.*—Dated June 11, 1912. Located in west end of Richmond District.

Complaint: The water supply is very inadequate in all sections where the service has been installed; not enough water to successfully fight fires, nor to properly flush the necessary sanitary utilities. In this district about 100 blocks with no service. Street work and sewers have been installed, and development is held back for lack of water supply.

Locality No. 5. *Wm. A. Butler.*—Dated March 27, 1912, and May 20, 1912. Located at 4010 Fulton Street.

Complaint: Last summer, at least half of the time, no water at all in the pipes between the hours of 6 A. M. and 8 P. M. Has complained in more than one letter to the Spring Valley Water Company about lack of water. Has no water in house or in Spring Valley Water Company pipes at time of writing second letter, May 20, 1912. Notes excessive rates, and no water at the time of day when people require it. A 2-inch main supplies over fifty families and two stables.

Locality No. 6. *R. G. Hamilton.*—Dated June 8, 1912. Located at Fortieth Avenue and Geary Street.

Complaint: "In my residence, no water whatever from about 9 A. M. until 7 or 8 o'clock P. M. Must draw water in buckets early in morning for use during day."

R. G. Hamilton.—Dated June 16, 1912. Located at Thirty-ninth Avenue and Geary Street.

Complaint: Large store, 200 feet distant from his residence, caught fire and was destroyed. No water could be obtained from hydrant, and when fire was discovered it might have been extinguished with a garden hose.

SOUTH SIDE OF GEARY STREET, BETWEEN THIRTY-NINTH AND FORTIETH STREETS, LOOKING EAST FROM FORTIETH STREET.

The Chief of the San Francisco Fire Department reported that a fire occurred in this block at 12:01 P. M. on June 16, 1912, and water pressure at hydrants at corner Thirty-ninth and corner of Fortieth Streets was not sufficient, and that fire engines were useless.

Locality No. 7. *E. G. Ely.*—Dated May 29, 1912. Located at 454 Thirty-sixth Avenue.

Complaint: Laid 250 feet of pipe at his own expense in 1904, from Geary Street main. Could not get water (1904 to 1906) from any of his faucets for three hours each day during summer months. From 1906 to 1908 could get no water each day from 7 A. M. until 9 P. M. during the summer months. (Geary Street main too small.) For the past four years has had practically no water service, winter or summer, between the hours of 7 A. M. and 10 P. M. There is no pressure in the fire hydrants during the daylight hours, even on Geary Street, between Thirty-fourth and Fortieth Avenues.

Four or five years ago the Spring Valley Water Company ran a 2-inch pipe from the Geary Street main at Thirty-fourth Avenue through Thirty-fourth Avenue to Clement Street, west on Clement Street to Thirty-sixth Avenue, and south on Thirty-sixth Avenue to a point 50 feet south of his residence. Mr. Ely then had to connect with this 2-inch pipe to obtain his water supply.

GEARY STREET, LOOKING EAST FROM THIRTY-SIXTH AVENUE.

The Chief Engineer of San Francisco Fire Department reported on May 28, 1912, the hydrant pressure at corner of Geary Street and Thirty-seventh Avenue 13 pounds, and at corner of Geary Street and Thirty-fifth Avenue 18 pounds pressure.

Western Addition

Locality No. 8. *Various Householders.*—Dated October 2, 1911. Located in Scott Street, between Pine and Ellis Streets.

Complaint: For the past two years the pressure in above district has not been sufficient. Both upper and lower flats have not enough water for domestic use or sanitary needs. The Spring Valley Water Company advises tanks on top of houses. Their plumber says pressure from street would not be sufficient to fill the tanks.

Mr. Murphy, Fire Chief, recently reported the lack of water for fire protection in this neighborhood.

SCOTT STREET, LOOKING NORTH FROM O'FARRELL STREET.

View showing a district in the heart of the city where there is not sufficient pressure in the mains to supply the upper stories of the residences.

The building material in the street is for the new Girls' High School, now being constructed.

SCOTT STREET, LOOKING NORTH FROM SUTTER STREET.

Another view of the same street, shown in preceding view, but taken three blocks further north.

Water service is inadequate in these residences.

The building material in the street is for a large apartment house under construction.

North Beach District

Locality No. 9. *California Fruit Canners' Association.*—Dated May 31, 1912. Located on blocks bounded by Beach, Leavenworth and Hyde Streets.

Complaint: Spring Valley Water Company mains in this vicinity are not of sufficient size to supply water for fire protection purposes. Impracticable to place fire hydrants on same. This is confirmed by the Chief of the Fire Department, who recommended a 12-inch and 8-inch main from the corner of North Point and Leavenworth Streets, up Montgomery Avenue to Beach Street, and thence along Beach Street to Hyde Street. This extension the Spring Valley Water Company has refused to make.

CALIFORNIA FRUIT CANNERS' ASSOCIATION PLANT, LOCATED AT BEACH AND HYDE STREETS.

A large factory building without sufficient water available for fire protection.

The Chief of the Fire Department reports that water mains in this vicinity are not of sufficient size to supply water for use of the fire engines.

U. S. ARMY SUPPLY DEPOT, CORNER VAN NESS AVENUE AND NORTH POINT STREET, SHOWING D. GHIRADELLI'S CHOCOLATE FACTORY ON THE EXTREME RIGHT.

These buildings are located one block westerly from the California Fruit Canners' Association plant, which is shown in the preceding picture.

Buena Vista District

Locality No. 10. *Haight and Ashbury Improvement Association.*—Dated June 1, 1912. Located in vicinity of Buena Vista Park.

Complaint: Protest against inadequate fire protection of Park Hill Avenue, between Fifteenth Street and Masonic Avenue; Masonic Avenue, from Park Hill Avenue to Congress Street, and on Congress Street south of Buena Vista Avenue. Delmar Street (formerly De Long) is also without adequate fire protection, a distance of 800 feet or more being without a fire hydrant. Same condition on Downey Street. All this district is built up with substantial structures.

DOWNEY STREET, LOOKING NORTH FROM END OF STREET.

Showing a thickly built-up residence street with no fire hydrant for about one-eighth of a mile.

CONGRESS STREET, LOOKING EAST.

Masonic Avenue is first street on left. Streets are paved with asphalt, and the district is rapidly building up with a good class of residences. Buena Vista Park shows at end of Congress Street.

Locality No. 11. *The Eureka Valley Improvement Association.*—Dated May 14, 1912. Located at Douglas Street, south of Nineteenth Street; also Fifteenth Street west of Castro Street.

Complaint: Protest against inadequate mains to give the service needed in this thickly populated section.

Also, request that fire mains be placed in said blocks. In case of fire this section would be almost entirely without water. Wish to be connected with Clarendon Heights Reservoir.

Locality No. 12. *Mrs. G. C. Roberts.*—Dated June 22, 1912. Located at Market Street Homestead, 32 Mars Street, vicinity of Seventeenth Street and Corbett Avenue.

Complaint: Water is filthy, and not fit to drink or use.

R. Hampton, Light and Water Inspector Department, Board of Public Works, states in answer to above complaint: "I have had a number of these complaints lately, principally caused by dead ends of mains, low pressure or poor circulation. I have reported them to the company, who send their men out to blow out the mains in the immediate vicinity, which gives temporary relief."

Locality No. 13. *Twin Peaks Association of Improvement Clubs.*—Dated June 24, 1912. Located in Twin Peaks District.

Complaint: Douglas Street, between Nineteenth and Twentieth Streets, is graded and contracts signed for paving, which are held up awaiting laying of an adequate water main.

There is now a 1½-inch pipe running irregularly, which partially supplies the thickly built-up blocks on each side, and a couple of short streets to the west of it.

DELMAR STREET, LOOKING NORTH FROM PIEDMONT AVENUE.

Showing a high-class residence street without adequate fire protection.

Mr. McClernon reports like conditions along Twentieth Street, between Church and Noe Streets. Since the failing of the Joost Wells, a private source of supply, the households and gardens along Romain Street were suffering, and on June 25th some thirty families living below the Corbett Road, and heretofore getting water from the Joost System, purchased the Joost supplying pipes, turned them over to the Spring Valley Water Company, and made agreements to take water from the company and pay its rates.

Bernal Heights District

Locality No. 14. *G. Toyne.*—Dated June 17, 1912. Located at Anderson Street, between Eugenia Avenue and Powhattan Street.

Complaint: Lack of water.

The following in regard to this complaint is extracted from report dated June 26, 1912, by R. Hampton, Light and Water Inspector, Board of Public Works:

"It is a case of no mains and very little water in a steadily growing neighborhood. This block is built up with about 22 homes which depend on their water supply from a 1½-inch pipe carried up from Eugenia Avenue about 150 feet, and the rest of the block is supplied by a ¾-inch pipe run by the property owners."

Locality No. 15. *Coso Avenue Improvement Club.*—Dated June 4, 1912. Located at Prospect and Coso Avenues (105-107-111 Elsie Street).

Complaint: Residents complain that there is no water supply in the neighborhood from early morning until late in the evening. Often have to carry water a distance of a block for domestic uses.

Locality No. 16. *South of Army Street Improvement Association.*—Dated June 22, 1912. Located at Anderson Street, between Eugenia and Powhattan Avenues.

Complaint: A permit has been granted to do permanent street work on this block. At present time only private water pipes exist, which give an insufficient supply. The whole block is built upon and occupied, except three lots. They petitioned for larger pipes to give the necessary supply for household use.

Locality No. 17. *Southern Alabama Street and Vicinity Improvement Club.*—Dated April 1, 1912. Located in Bernal Heights District, bounded by Bradford Street, Carver Street, Esmeralda Street, Rosecrantz Street and Mayflower Street.

Complaint: Residents protest against lack of water pressure, and also water not in sanitary condition. A 1-inch pipe supplies these residents.

Fairmount District

Locality No. 18. *Diamond and Twenty-eighth Streets Improvement Club.*—Dated April 2, 1912. Located at Twenty-ninth Street, between Diamond and Douglass Streets.

Petition: Petition regarding need of a water main in this block. Residents to get water have to tap the main on Diamond Street, and those located on the hill have very little water pressure.

LAIDLEY STREET, LOOKING EAST FROM MATEO STREET.

The smaller pipe on the left is Spring Valley Company's main. District where consumers claim there is practically no water from 8 A. M. to 10 P. M. daily.

Pipes are now exposed during street work.

Consumers want proper main laid before street work is completed.

Locality No. 19. *Various Householders.*—Dated May 31, 1912. Located in Fairmont Tract, Block 12, 316 to 396 Laidley Street.

Petition: Petition for relief in regard to water supply. Claim they are daily without water from 8 A. M. until 10 P. M., and only 200 feet distant from a 30-inch main of Spring Valley Water Company.

NORTH SIDE OF MATEO STREET, BETWEEN LAIDLEY AND CHENERY STREETS.

Improvements in neighborhood of Laidley Street, showing character of homes and improvements in district.

Ocean View District

Locality No. 20. *Various Householders.*—Dated April 8, 1912. Located on Columbia Heights; district bounded by Josiah Street, Majestic Avenue, Ridge Lane and Summit Avenue.

Petition: That immediate consideration be given to the serious condition of lack of water in this district. May be forced

BELL AVENUE, LOOKING EAST FROM COUNTY ROAD.

Typical scene of Ocean View District, showing character of homes and improvements where there is insufficient water for domestic use and fire protection.

to abandon their homes. Have not sufficient water for ordinary household needs.

Locality No. 21. *Various Householders.*—Dated May 15, 1912. Located in district bounded by County line, Junipero Serra Boulevard, Palmetto Street and Head Street.

Petition: For immediate relief. An inadequate water service in this district.

Locality No. 22. *The West End Improvement Club.*—Dated June 12, 1912. Located between Lowell and Gutenberg Streets, and southeast of Hanover Street, including Bellevue Avenue.

Complaint: Residents are hardly able to get enough water for drinking purposes. Have to draw water at night to use for cleansing purposes and domestic use during the next day.

LOWELL STREET, LOOKING NORTHWEST FROM CORNER OF LOWELL AND HANOVER STREETS.

District where water pressure is so low that consumers have to draw water at night for domestic use, and claim they can scarcely get enough for drinking during day.

Sunset District

Locality No. 23. *A. P. Sutkamp.*—Dated June 4, 1912. Located in Parkside, 918 Taraval Street, near Twenty-first Avenue.

Complaint: On June 3, 1912, was without water from 9 A. M. to 3:45 P. M.

PARKSIDE, LOOKING NORTHEAST FROM TWENTY-SECOND AVENUE AND TARAVAL STREET, SHOWING 918 TARAVAL STREET.

Locality No. 24. *B. Armstrong.*—Dated April 4, 1912. Located at Ocean Beach, 1790 Forty-sixth Avenue.

Complaint: From May to October, without water from 8 A. M. to 9:30 P. M. every day. Also, absolutely without water for fire protection during these hours.

INADEQUATE FIRE PROTECTION IN DIFFERENT SECTIONS OF THE CITY.

Reports of the Chief Engineer of the Fire Department to the Board of Supervisors

San Francisco, July 1, 1912.

To the Honorable the Board of Supervisors.

Gentlemen—This board respectfully submits herewith the attached reports received from the Chief Engineer of this department relative to the inadequacy of the water pressure and the lack of water supplied by the Spring Valley Water Company at certain fire hydrants in different portions of the city, with a request that your Honorable Board take some steps to compel the Spring Valley Water Company to furnish sufficient water for fire protection purposes in all sections of the city that are at present covered by its water mains.

Very respectfully yours,
(Signed): BOARD OF FIRE COMMISSIONERS,
By FRANK T. KENNEDY, Secretary.

(Copy.)
Engine Company No. 36,
San Francisco, June 16, 1912.

Capt. F. Grote, Acting Battalion Chief, Thirteenth District.

Sir—I responded with this Company to box 718, at 12:01 P. M. On arrival at fire found that 8 Chemical was connected to hydrant at Thirty-ninth Avenue and Geary. Took hydrant at Fortieth Avenue. Pressure on this hyurant at start, 19 pounds. When Engine Company 26 relieved 8 Chemical at hydrant at Thirty-ninth Avenue, pressure dropped to zero; pressure on hydrant at Fortieth Avenue at time of leaving, 14 pounds.

Respectfully,
(Signed): W. F. BOYNTON, Lieutenant;
J. H. DEVER, Captain.

(Copy.)
San Francisco, June 17, 1912.

Thomas R. Murphy, Chief of Department.

Sir—I respectfully submit the following report: At 12:01 P. M., June 16th, I responded to alarm from box 718. On arriving at the fire I saw that Chemical No. 8 had taken a hydrant at the northeast corner of Geary and Thirty-ninth Avenue, and had led across the street to the southwest corner, where the fire was.

The water was just flowing through the hose and falling off the end of the pipe to the ground. Not being able to reach the fire, the line was discarded as useless.

Engine No. 36 took a hydrant at Geary and Fortieth Avenue, and with the engine working hard we were able to get one small stream.

Engine No. 26 came in and took the hydrant that Chemical No. 8 had given up, and when it was working took the water away from Engine No. 36, leaving Engine No. 36 useless.

Respectfully submitted,
(Signed): FRED GROTE,
Acting Battalion Chief No. 13.

(Copy.)
San Francisco, June 18, 1912.

Mr. Thomas R. Murphy, Chief Engineer, S. F. F. D.

Dear Sir—I desire to report that the hydrant located at the northeast corner of Leavenworth and Francisco Streets has been without water for some time past.

This condition is due to the fact that the reservoir at Francisco and Bay Streets is too low to supply water at this elevation, therefore I would respectfully recommend that this hydrant be taken out, as it is an unnecessary expense to the department.

Respectfully yours,
(Signed): HENRY RICE, Foreman Hydrantman.

(Copy.)

San Francisco, June 19, 1912.

To Thos. R. Murphy, Chief of Department.

Sir—I respectfully submit to you the following report: Engine Company No. 6 reported to box 521 at 2:40 P. M., this date. The fire was on Rhode Island Street, between Eighteenth and Nineteenth Streets. I took the company to Nineteenth and Vermont Streets and took the hydrant on the southeast corner, a single ball top. I led into the fire and sent back for water. The engineer sent back word there was no water in the hydrant. I was ordered to take up and go back to quarters.

Respectfully submitted,
(Signed): GEORGE R. LAWSON, Captain.

June 14, 1912.

To the Honorable Board of Supervisors.

Gentlemen: We enclose herewith copy of communication this day sent to the Spring Valley Water Company. We urge upon you the necessity for immediate action on the part of the Spring Valley Water Company. The menace to the city from lack of water mains for fire protection purposes is grave enough, without adding to it this additional fear, unpardonable in view of the actual existence of the mains. The matter cannot be taken up too soon by your honorable body.

Yours respectfully,
(Signed): BOARD OF FIRE COMMISSIONERS,
FRANK T. KENNEDY, Secretary.

June 14, 1912.

Spring Valley Water Company, Sutter St., City.

Gentlemen—At a regular meeting of the Board of Fire Commissioners held on the 13th instant, the recommendation of the Chief Engineer was approved, and it was ordered that your attention be called to the fact that a greater part of the time there is no water in the mains in Parkside. All the hydrants on T Street, between Nineteenth and Thirtieth Avenues, were tested on June 8th, at about 3 P. M., and found to be dry. This is a serious matter, and we earnestly request that you have same attended to at once.

Yours respectfully,
BOARD OF FIRE COMMISSIONERS,
Secretary.

(Copy.)

HYDRANT PRESSURE REPORT.

Date.	Location.	Pressure.
May 28, 1912.	Northeast corner Golden Gate Ave. and Hyde St.	35 pounds.
	Southeast corner Turk and Hyde Sts.	33 "
	Southwest corner Turk and Hyde Sts.	34 "
	Northeast corner Hyde and Turk Sts.	35 "
	Southeast corner Hyde and Eddy Sts.	31 "
	Southeast corner Eddy and Hyde Sts.	31 "
	Southwest corner Eddy and Hyde Sts.	32 "
	Northeast corner Hyde and Eddy Sts.	32 "
	Southeast corner Eddy and Larkin Sts.	25 "
	Park and Holly	15 "
	Mission and Richland	21 "
	College Ave. and Mission	24 "
	Bennington and Highland Ave.	14 "
	Bennington and Elert	17 "
	Bennington and Cortland	18 "
	Cortland and Moultrie	21 "
	South side of Richland, 5 feet west of Murray	15 "
	South side of Richland, 400 feet west of Murray	23 "
	South side of Park St., 7 feet east of Leese	15 pounds.
	East side of Bennington, 5 feet north of Highland	.. "
	San Jose Ave. and Geneva	22 "
	Southwest corner Richland and Murray	15 "
	Northwest corner Crescent Ave., opposite Murray	28 "
	East side Dolores, opposite Jersey	20 "
	Northwest corner Lombard and Van Ness Ave.	16 "
	Southwest corner Union and Hyde Sts.	19 "
	Northwest corner Union and Hyde Sts.	.. "
	Northwest corner Filbert and Hyde Sts.	7 "
	Union, between Hyde and Leavenworth Sts.	10 "
	Northwest corner Lombard and Van Ness Ave.	16 "
	Southeast corner Pacific Ave. and Lyon St.	10 "
	Northeast corner Golden Gate Ave. and Jones St.	39 "
	Southwest corner Eddy and Jones Sts.	42 "
	Southwest corner Geary and Thirty-fifth Ave.	18 "
	Southwest corner Geary and Thirty-seventh Ave.	13 "
	Northeast corner Geary and Thirty-ninth Ave.	15 "
	Southeast corner Cliff Ave. and Forty-third Ave.	10 "

STREETS ON WHICH THERE ARE NO SPRING VALLEY MAINS FOR FIRE PROTECTION.

(List furnished by the City Engineer.)

In the Flint Tract:

Masonic Avenue, from Piedmont to Albany Street; Congress Street; Levant Street; States Street; Flint Street; President.

Park Hill Avenue from Masonic Avenue to Fifteenth Street.

Beaver Street, from Castro Street to Fifteenth Street.

Sixteenth Street, from Castro Street to Masonic Avenue.

In the Pope Tract:

All streets in this tract.

In the Park Lane Tract:

Olympus Street; Clifford Street; Upper Terrace; Lower Terrace; Saturn Street; Pluto Street; Juno Street; Jupiter Street; Clayton Street; Parnassus Street to Ashbury Street.

Deming Street.

Eighteenth Street, from Danvers Street to Corbett Avenue.

In the Market Street Homestead Tract:

Groveland Street; Eagle Street; Mono Street; Falcon Avenue; Carson Street; Seward Street; Acme Alley; Corwin Street; Blair Street; Stanton Street; Yukon Street; Glendale Street; Grand View Avenue; Romain Street; Burnett Street; Dixie Street; Hopkins Street; Golding Street.

In the Fairview Terrace:

Bellevue Street, from Twenty-fourth Street to Thirtieth Street.

Hoffman Avenue, from Twenty-fifth Street to Thirtieth Street.

Douglass Street, from Clipper to Thirtieth Street.

In the Stanford Heights and Sunnyside Addition:

From Clipper Street on the north; Thirty-fourth Street on the south; Fowler Avenue on the west, to Burnett Avenue on the east, comprising 70 square blocks.

In the Sunnyside District:

There is an 8-inch main on Sunnyside Avenue for 5 blocks.

On Joost Avenue for 3 blocks.

On Arcadia Street for 1 block.

On Genessee Street for 2 blocks.

On Flood Avenue for 1 block.

This district comprises 50 square blocks.

Glen Park Terrace and Castro Street Additions:

There are about 30 blocks in this district, with water mains in 4 blocks.

In the Bernal Heights District:

Winfield Street; Elsie Street; Bonview Street; Eugenia Avenue to Soso Avenue.

Andover Street and Moultrie Street, from Eugenia Avenue to Esmeralda Avenue.

Anderson Street; Ellsworth Street; Gates Street; Folsom Street; Banks Street; Prentiss Street; Nevada Street; Nebraska Street and Bradford Street, from Cortland Avenue to Esmeralda Avenue.

On the southern slopes of Bernal Heights, bounded by Army Street; Alabama Street; Nebraska Street; Cortland Avenue and San Bruno Avenue, comprising about 50 square blocks.

In the Holly Park District:

From Holly Park south to San Bruno Avenue, between Crescent Avenue and Cortland Avenue, comprising about 65 blocks.

In the Excelsior District:

In this district there are about 100 square blocks, with water mains in 17 blocks.

In the University Mound District:

In this district there are about 200 square blocks, with no water mains of any description.

In the South San Francisco District:

From Revere Avenue to Paul Avenue there are no mains excepting that on Railroad Avenue.

From Paul Avenue and Gilman Avenue to the county line, no mains.

In the Lake View District:

From Ocean Avenue to Summit Street, between San Jose Avenue and Harold Avenue, comprising 30 blocks.

In the Ingleside District:

From Ocean Avenue to Lakeview Avenue.

From Harold Avenue to Junipero Serra Boulevard, excepting a main for 8 blocks on Holloway Avenue.

In Horner's Addition:

Army Street; Twenty-seventh Street; Duncan Street; Twenty-eighth Street; Valley Street; Diamond Street; Sanchez Street; Twenty-ninth Street; Day Street, and Thirtieth Street, from Sanchez to Noe Street.

In the Potrero District:

Sixteenth Street, from Kansas Street to the bay.

Seventeenth Street, from Kansas Street to the bay.

Mariposa, from Potrero Avenue to Arkansas Street.

Eighteenth Street, from Potrero Avenue to Mississippi Street.

Nineteenth Street, from Potrero Avenue to Connecticut Street.

Mississippi to Tennessee Street.

Twentieth Street, from Potrero Avenue to Wisconsin Street, and from Mississippi to Kentucky Street.

Twenty-first Street, from San Bruno Avenue to the bay.

Twenty-second Street, from Wisconsin to Iowa Street.

Twenty-third Street, from Rhode Island to Pennsylvania Street.

Kansas Street; Rhode Island Street and De Haro Street, from Seventeenth Street to Twenty-third Street.

Carolina Street, from Alameda to Army Street.

Wisconsin Street, from Sixteenth to Twentieth Street, and from Twenty-second to Army Street.

Arkansas Street, from Mariposa to Twentieth Street, and from Twenty-first to Army Street.

Connecticut Street, from Twenty-first Street to Army Street.

Missouri, Texas and Mississippi Streets, from Twentieth to Army Street.

Iowa Street, from Mariposa to Twenty-first Street.

In the West Richmond and West Clay Park District:

California Street, from Twenty-fourth Avenue to Thirty-third Avenue.

Lake Street, from Twenty-seventh Avenue to Thirty-third Avenue.

Drake Street, from Twenty-fourth Avenue to Thirty-second Avenue.

Twenty-fifth Avenue, from Clement Street to its northerly terminal.

Twenty-sixth, Twenty-seventh, Twenty-eighth, Twenty-ninth, Thirtieth, Thirty-first, Thirty-second and Thirty-third Avenues, from Clement Street to their northerly terminals.

In the Richmond District (Central):

Clement Street, from Sixteenth Avenue to Twenty-fourth Avenue.

California Street, from Fourteenth Avenue to Eighth Avenue.

Lake Street, from Sixteenth Avenue to Nineteenth Avenue.

Sixteenth, Seventeenth and Eighteenth Avenues, from Geary to Lake Street.

Nineteenth Avenue, from Geary Street to California Street.

Twentieth Avenue, from California Street to Lake Street.

Twenty-first Avenue, from California Street to Lake Street.

In the district from Geary Street to Golden Gate Park, and from Ninth Avenue to the ocean, there are practically no mains at all. From Forty-sixth Avenue west there is a 4-inch main which is of no use for fire protection.

In Masonic Avenue, from McAllister Street to Geary Street, no main.

In the Sunset District, from Twelfth Avenue to the ocean, and from Lincoln Way southerly, with the exception of about 5 blocks, there are no mains.

Among the streets without water mains listed above are many where there are as yet no houses and the Company may claim they cannot be expected to go to much expense in aiding real estate speculation by laying mains in uninhabited districts, but for much of this territory there can obviously be a proper rejoinder to such a statement in the fact that men cannot be expected to build houses on streets where there are no water mains; and it is certain that real estate development and the building of homes in much of the above territory is being improperly retarded by inadequate water service, and residents who would otherwise settle in San Francisco are driven down the peninsula or across the bay.

The following statements are abstracted from a report recently completed by Marsden Manson, City Engineer.

The principal districts which are without adequate water supply are the following:

Richmond, Sunset, University Mound, Excelsior, Homestead, Potrero Heights, Sunnyside, Ingleside and the district on the east side of Holly Park.

Parts of these districts are entirely without water and others are inadequately supplied. In none of the above are the existing water mains of sufficient size to enable the Fire Department to cope with a fire of much magnitude. The distribution of the houses in these outlying districts shows plainly the effect of the inadequate water supply. This is particularly noticeable in the Richmond District where those sections supplied with a sufficient service for domestic use are thickly built upon, and those with an insufficient supply are only partly built up, while those sections without water located immediately adjacent are not built upon at all.

Many parts of these districts will be rapidly built up so soon as the property owners are assured that adequate water supply mains are to be installed.

Appendix No. 8—Cost Data.

BASIS FOR ESTIMATE OF CAPACITY AND COST OF HETCH HETCHY AQUEDUCT TUNNELS

Notes by JOHN R. FREEMAN, Engineer.

Water Carrying Capacity

Substantially all of these will be pressure tunnels, under barely sufficient pressure to permit regulating the hydraulic gradient and thus the rate of delivery, while always keeping the downstream end of the tunnel filled. The pressure type is preferable in giving much more prompt response to changes in rate of draft and permits much better control in developing power and in providing increased discharge in emergencies. The actual downstream slope of the tunnel will seldom be less than one foot drop in five thousand feet, in order to give fairly prompt drainage for inspections. No adverse grades will be allowed for the purpose of facilitating drainage toward the shaft during construction, where such grades would tend to create air pockets.

All tunnels will be lined throughout with a good grade of Portland cement concrete, having a general thickness to the prescribed line of excavation of eight inches on the sides and top and from four to six inches on the bottom. A minimum thickness of four inches over small projections will be allowed.

A circular cross-section is preferable so far as facility in construction will permit, being much stronger against infiltration pressures and slightly better hydraulically and in economizing cement, and although a horseshoe section may be used, this must present some substantial convexity throughout the walls, in order that the arch effect thus obtained may strengthen this thin lining against external seepage pressure, when the water is suddenly withdrawn. The many miles of pressure tunnels recently built for the New York Board of Water Supply are all of circular cross section.

The water carrying capacity of the Hetch Hetchy tunnels will be computed with the same co-efficient of roughness that is used in designing the Los Angeles aqueduct, namely, with $n = 0.014$, in the Kutter formula. This is liberal enough to cover some roughness of finish and to provide against the retarding effect of moss-like growths, such as was noted in the Boston aqueduct, and will allow for retardation by some slight deposits of sand on the bottom, although there will be small chance of this under the high velocities proposed. While new and clean there is little doubt that with good smooth finish of the interior these concrete-lined tunnels, particularly if plastered as on the Los Angeles work, would show $n = 0.011$ and carry 28 per cent more water than has been estimated with the hydraulic gradient shown in the profiles on the accompanying maps.

The thirty-four miles of the Hetch Hetchy tunnels between the intake in the Sierras and the San Joaquin Valley could all be cheapened materially by giving them steeper hydraulic gradients than those shown in the profile presented, thereby permitting smaller diameters. Any sacrifice of future hydro-electric power which this would involve would not be of material importance, but I have selected these diameters in order to permit increase in carrying capacity by putting greater pressure on the upstream end, should this become desirable, while replenishing a reservoir after interruption or for bringing down a surplus while water is plenty, or for permanently carrying more than 400 million gallons daily.

Altho the grades and locations shown on the accompanying maps and profiles may be varied following a full geological exploration and a more complete cost analysis the general effect of such change will be to better the design and to decrease its cost as compared with that upon which the estimate is based.

Natural Conditions Along the San Francisco-Hetch Hetchy Aqueduct

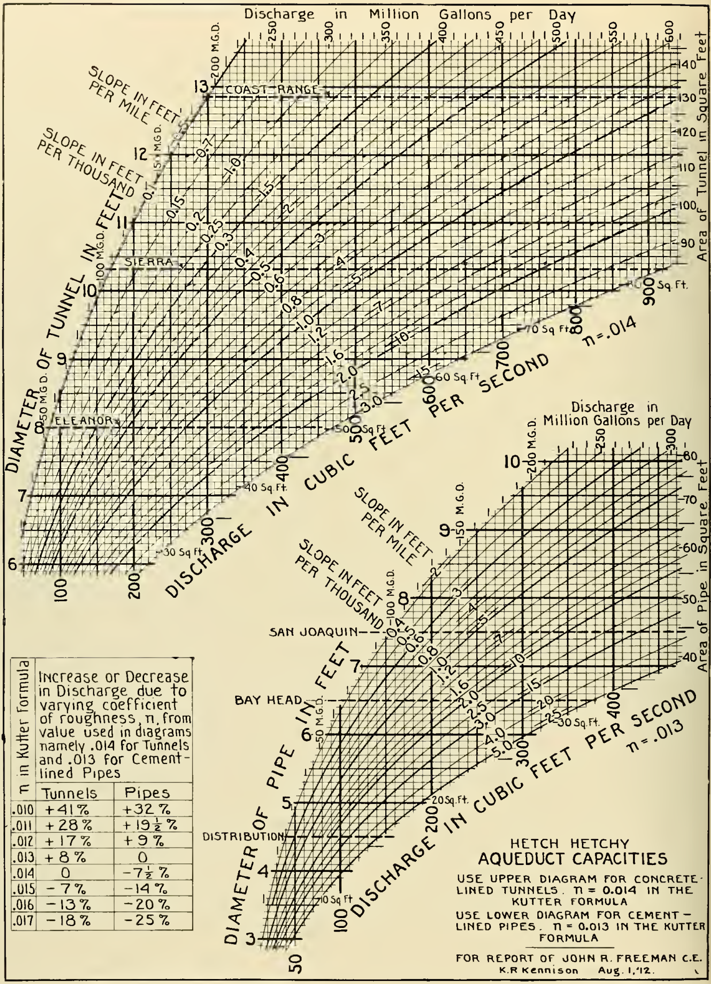
A reconnaissance by Mr. Horace Ropes of this proposed San Francisco aqueduct line shows that the greater part of this tunneling will be done under favorable conditions so far as external conditions are concerned. My own briefer inspection confirms this. Mr. Ropes was the engineer directly in charge of the construction of the aqueduct tunnels of the Boston Metropolitan Water System, and made various location studies for the aqueducts for the additional supply of New York, and is also experienced in heavy construction under Western conditions.

The main highways run fairly near to most of the shaft sites; the country is moderately well wooded and well watered; appearances indicate that sand, gravel and broken stone can be obtained near at hand at moderate cost, the climate is comfortable summer and winter. The geological conditions are particularly favorable for tunneling in the sound dry granites near Hetch Hetchy

Thence proceeding downstream to the Early Intake for about five miles to the South Fork, the line will also be in good granite and probably nearly all of this upper twenty-one miles will be safe without timbering. For the fourteen miles downstream from South Fork to the power drop, the tunnels also promise to involve no special difficulty, being in the ordinary rocks of the cretaceous series. Thence to the Tuolumne River our line has been moved a little in order to avoid the bed of serpentine (probably slippery) which exists northwesterly from Red Mountain bar, and thence to the edge of the San Joaquin Valley, altho there may be a mixture of slates and sandstones of various degrees of hardness, the topography promises dry work and no uncommon difficulty. The region of doubt and difficulty is found mainly in crossing the Mt. Hamilton-Diablo range, anywhere between Altamont and Tesla, of which mention is made later, and for this reason the line has been moved south.

About 28 miles of the line is covered by the geologic folio of the Sonora section of the U. S. Geological Survey, and Professor J. C Branner, Vice President and head of the Geological Department of Stanford University, has long been studying the areas directly east and west of this and collecting data for the folios of the Geological Survey and making also special studies of the water-bearing basin surrounding Livermore. We were most fortunate in securing his expert services and advice on selecting our route thru the region south of the old coal mines of Tesla and in trying to steer clear of the vast, deep and high-piled beds of pliocene gravels south of Livermore, and under his advice moved south about two miles the line previously selected from our topographic study, incurring deeper shafts and greater length, in the effort to avoid deep wet beds of gravel and clay.

We have not taken as a basis for our estimate of cost anything so favorable as the tunnels now being excavated about two miles north of our line, as part of an irrigation project taking water from the Stanislaus River into the Oakdale District, altho we may hope for some ground equally favorable. Here a tunnel about ten feet in diameter, about 1,450 feet long, was recently driven from its two ends and "holed thru" in thirty days, thus showing a progress of twenty-four feet per day. On the same project, another tunnel, about a mile and a third in length, is being driven from two shafts and two portals at a rate which is said to have averaged about eleven feet per heading, including delays. Its present progress with two shifts of men per twenty-



n in Kutter Formula	Increase or Decrease in Discharge due to varying coefficient of roughness, n, from value used in diagrams namely .014 for Tunnels and .013 for Cement-lined Pipes	
	Tunnels	Pipes
.010	+41%	+32%
.011	+28%	+19½%
.012	+17%	+9%
.013	+8%	0
.014	0	−7½%
.015	−7%	−14%
.016	−13%	−20%
.017	−18%	−25%

HETCH HETCHY
AQUEDUCT CAPACITIES

USE UPPER DIAGRAM FOR CONCRETE-LINED TUNNELS. n = 0.014 IN THE KUTTER FORMULA

USE LOWER DIAGRAM FOR CEMENT-LINED PIPES. n = 0.013 IN THE KUTTER FORMULA

FOR REPORT OF JOHN R. FREEMAN C.E.
K.R Kennison Aug. 1, '12.

four hours is said to be at the rate of twenty-four feet per heading per day. It is stated that each shift of ten men gets in two rounds of shots drawing six feet, and under a sub-sub-contract the workmen are said to be excavating this for $6.00 per lineal foot for drilling, blasting and mucking. This sandstone is drilled with hand augers, but is nevertheless strong enough to stand alone, so that only a very small portion is timbered. These two tunnels present ideal conditions for safe, cheap and rapid work.

We also have reports of low cost tunnel work a few miles north of our location now in progress for the South San Joaquin Irrigation District. Though we hope for some equally favorable situations it is safer to assume them offset by "bad ground" on other parts of the line.

Unit Costs for Tunnels Estimates

As a guide in estimating unit costs on the San Francisco lines, much reliance will be placed upon the experience on the tunnels of the Los Angeles aqueduct, because of these having been very recently constructed, under California conditions, by day labor, with careful attention to keeping account of the several items of cost. The writer was a member of the Board of Engineers appointed by the City of Los Angeles to study that project in its early stages and to prepare the estimates of cost upon which the project was financed. Thru the skill and devotion of William Mulholland, Chief Engineer, that work is being done at a cost much less than was estimated, and the writer has inspected the work while in progress and studied the natural conditions, and from personal inspection and from that of other engineers of experience, the writer believes the quality of workmanship on the Los Angeles tunnels is admirable.

In general the prevailing rate of wages for an 8-hour day was for common labor, $2.25 to $2.50; drill runners, $3.00 plus found; muckers, $2.50; blacksmiths, $3.50 to $4.00; compressor men and mechanics, $3.00 to $3.50; shift bosses, $3.50 to $4.00; foremen, $125 to $150 per month. Commonly, 3 shifts were worked in 24 hours.

It appears from inspecting the location that several miles of the Hetch Hetchy tunnels will present the same favorable conditions for rapid progress and for low cost that were obtained in the most favorable sandstone tunnels of the Los Angeles aqueduct, and we find no ground where the conditions will probably be worse than on the north end of the Los Angeles "Elizabeth Lake" tunnel. On the whole, from repeated personal inspection of both the Los Angeles and the Hetch Hetchy surface conditions, I believe the natural conditions average as favorable along the San Francisco-Hetch Hetchy line. Save for the uncertainties in the ground south of Tesla, I regard the San Francisco conditions as on the whole more favorable.

But it must be kept in mind that these Los Angeles tunnels have been constructed under exceptionally competent engineering management, by day labor, managed with remarkable tact. Looking backward, the Chief Engineer and his principal assistant tell me that now they see many places where further economies could have been effected, but it is not safe to reckon upon such in advance. Increase of cost on the San Francisco work would follow bad labor conditions or mistaken legislation, or anything short of the very best management, and for all of these possibilities an excess cost factor will be discussed later.

Data for Hard Rock Tunnels Under Adverse Conditions

The Elizabeth Lake section of the Los Angeles aqueduct is slightly larger in diameter and 10% larger in area of cross-section than that which I have adopted for substantially all of the hard-rock tunnels in the Sierra Division between the Hetch Hetchy reservoir and the edge of the San Joaquin Valley. It is of somewhat smaller diameter than the tunnels proposed in the softer formations east of the San Joaquin Valley and beneath the Mission Pass.

This Elizabeth tunnel is a particularly prudent cost guide so far as natural conditions are concerned, because it was driven in rock much less favorable than the sound, dry rock which will probably be found in the Sierras and a cursory inspection along our line, with due regard to the natural drainage of the formation, indicates that for no important distance on the San Francisco line, except in the doubtful ground south of Tesla and Livermore, will there be any such adverse conditions as were found in the wet, crushed granite within the broad broken zone along the great St. Andreas fault which passes beneath Elizabeth Lake, which fault is of such importance as to be marked in the report of the California Earthquake Commission, altho it gave no movement in the slip of 1906.

DATA FROM ELIZABETH TUNNEL, LOS ANGELES AQUEDUCT.

(See above for description of conditions under which this work was done.)	Average for all work for the first 26 months to December 31, 1909, including 60 per cent of entire length.						For whole period of forty months to March, 1911.		
	From North Portal, in bad, broken, rotten granite; heavy dangerous ground; required timbering, 96 per cent. of length.			From South Portal, in good, sound, hard granite, excellent conditions; only 20 per cent required timbering.			Averages for the whole length of tunnel, 5.09 miles.		
	Feet.	Per foot.	For total length.	Feet.	Per foot.	For total length.	North 13,370 feet, per foot.	South 13,500 feet, per foot.	For 26,870 feet, total length.
Excavation, drilling, steel, labor and power	7,637	$12.94		7,585	$16.62		$11.25	$14.65	$12.95
Mucking	"	12.85		"	12.13	Grav.	11.70	11.10	11.40
Drainage	"	.52	P'mp'd.	"	.12	flow.	.45	.17	.31
Ventilation	"	.31		"	.63		.22	.41	.31
Power and light for drilling, hauling, etc	"	5.21		"	5.23		5.55	4.93	5.24
							$29.17	$31.26	$30.21
Local engineering and surveying	"	1.61		"	1.25				1.07
Proportion of shaft and portal cut	"	.88		"	.05				.62
		$34.32	$34.32		$36.03	$36.03			$31.90
Timbering and dry packing	7,315	6.59	6.31	1,681	5.75	1.27	16,455 ft. at $8.74,		5.35
Total		$40.91	$40.63		$41.78	$37.30			$37.25
Final cleaning up and knocking off projections of rock, average cost per foot.									1.50
Lining with concrete							16,455 ft. at $11.03,		11.03
Average for whole length, including lining		—			—				$49.78

The cost of equipment is not included above, but its cost of installation and maintenance is included.

The comparative cost of excavating in the bad ground from the north portal and the good ground from the south portal gives an excellent illustration of the general experience that the excess in cost of timbering badly shattered rock is largely offset by the smaller cost of blasting and excavating the badly broken rock.

COST PER LINEAL FOOT FOR LOS ANGELES AQUEDUCT TUNNELS

DATA ON COST OF TUNNELS ON LOS ANGELES AQUEDUCT

80 Headings, 24 Miles, Widely different formations

Condensed from Monthly Reports to Chief Engineer (by J.R.F. ; June, 1912. E. & O.E. Subject to Revision.)

Tunnel Number	72	1, 1-A, 1-B	2, 2-A	3	4	7	8	12	13	14	15	16	17	17-AB	27, 28	29, 31-33	35	38	39	42	43	46	P 2-5	73	75, 76	77	78, 79	82, 84, 85	89	93	94, 96	100-2	104	P 8, 9	P 10-14	17-M
General Character of Rock	GRANITE																							SOFT ROCK												
Division	Elizabeth	5, Little Lake						5-A, Grapevine							7, Jawbone								14	11, Saugus										14		7
Date of Report	Mac'11	Aug'09	Jan'12		Aug'09	Dec'09	Jan'12	Dec'09	January 1912				Aug'09	Jan'12	Dec'09	Aug'09	Dec'09		Aug'09	Dec'09	Aug'09		Jan'12	Dec'09	Aug'09	December'09			Jan'12	Dec'09	Aug'09	Dec'09		Jan'12		Letter Aug 9'11
Area to Prescribed Line of Excavation - Sq. Ft.	135 tim 113 unt.	95 - timbered 77 - untimbered													101 timbered 82 untimbered								145 tim 120 unt	181 timb. 160 untim.			138 timbered 114 untimbered							145 - timb 120 - untm.		122 tim. 100 untm.
Net Width x Hight - Ft.	9'-6"x 10'-10"	7 ft. 10 in. x 8 ft. 5 in.													8 ft. 0 in. x 9 ft. 1 in.								About 10x11.5	11 ft. 6 in. x 13 ft. 1 in.			9 ft. 8 in. x 10 ft. 8½ in.							About 10x11.5		8'-6"x 10'-6½"
Net Cross Section after Lining - Sq. Ft.	88	58													63								Abt. 97	132			92							Abt. 97		79
Kind of Rock	North Broken Wet Granite South Sound Dry	Soft Broken Granite	Medium Granite	Decom. Granite Slips at Talcose Planes	Hard Blocky Granite	Harder than 3 Biotite Granite	Decom. Granite Fewer Slips than 3	Hard Gray Granite Few Slips	Snd. Granite Some very hard Syenite Intrusions	Hard Granite			Hard Gray Granite Few Slips	Hard Granite	Faulty Decomposed Granite		Disturbed Blocky Jointed Granite Very Wet Treacherous		Hard Granite	Decom Granite Homogns Easily Excavated	Decomp Granite and Porphyry		Hard Granite	Hard Slate Broken Undisturbd in places	Compact Sand Gravel and Clay								Quicksnd and Caving Ground	Sandstn	Slate and Schist	Incipient Sand-Stone
Number of Headings	2	5	2	1	2	1	1	2	1	1	1	1	2	2	2	4	1	2	1	1	1	1	4	1	2	2	2	5	1	2	5	3	2	3	9	2
Progress during Past Month - Ft. per Heading		193	109		127	187		301					224	201				172	152				272			89		378		54	141		263	273	172	Complete
Total Length Tunnelled - Ft.	26870	1320	2954	4044	1392	1534	2560	2275	1972	859	895	2723	1958	12963	4284	5047	5128	2791	2381	3110	3246	1523	4470	3271	3820	2947	1185	3976	861	3049	3265	965	6099	2509	5058	10596
Total Timbering - Ft.	16455	549	2805	3570	1112	1319	662	90	87	30	0	22	142	609	1643	2359	2463	2075	1144	988	2174	661	120	2800	1518	2068	37	3490	861	2372	3265	965	5963	1779	4005	1982
% of Length, timbered	61	42	95	88	80	86	26	4	4	4	0	1	7	5	38	47	48	74	48	32	67	43	3	86	40	70	3	88	100	78	100	100	98	71	79	19
Total Length of Lining to Date — Bottom - Ft.															1482	3385	144			2776					1877						•	255	1075			
Total Length of Lining to Date — Sides & Arch - Ft.															4293	5050	3797			3117	2415			1556	3279		1048					759	4677			
Total Length of Lining to Date — Total - Ft.	15955		976	3523			846		1972	859	895	2723						1174				1521				2087			265							10596
Costs																																				
Excavation incl Mucking per Ft.	31.71	Hand 6.89	H & M 8.62	Mach 13.58	Mach 12.13	Mach 12.15	Mach 15.00	Mach 19.84	Mach 25.07	Mach 23.74	Mach 24.05	Mach 21.41	Mach 16.79	Mach 21.14	13.22	13.57	18.41	18.06	Mach 17.05	11.33	11.41	10.75	Mach 21.05	Hand 26.95	Hand 16.62	Hand 19.42	Hand 8.26	Hand 7.69	Hand 7.62	Hand 9.89	Hand 9.12	Hand 9.25	Hand 17.65	H & M 17.03	H & M 16.22	7.96
" " " per c.y.	6.75	2.20	2.47	3.96	3.59	3.55	4.95	6.90	8.72	8.29	8.45	7.49	5.79	7.35	4.00	4.03	5.45	5.07	5.05	3.48	3.25	3.22	4.71	4.09	2.67	3.00	1.94	1.54	1.49	2.01	1.78	1.80	3.46	3.34	3.13	2.06
Timbering and Dry Packing per timbered Ft.	8.74	1.87	3.26	4.12	2.54	3.39	5.92	3.58	3.13	4.67		4.97	3.95	7.28	2.73	2.18	4.68	5.62	3.58	1.28	.97	2.60	4.10	7.31	3.34	5.47	2.07	1.60	1.38	2.99	3.85	3.62	5.41	7.81	7.23	1.56
" per excavated Ft.	5.35	.78	3.10	3.69	2.03	2.92	1.53	.14	.14	.16		.04	.29	.34	1.05	1.92	2.25	4.18	1.72	.41	.65	1.13	.11	6.27	1.33	3.84	.06	1.40	1.38	2.32	3.85	3.62	5.29	6.55	5.72	.79
Cost of Lining per Lined Ft. — Sand, Rock Gravel			1.51	1.37			1.38		1.14	1.01	.94	1.06												Cost Ex. & M. = abt 36 Cost Ex. & M = abt 18					2.72							
Cement			3.29	3.33			3.43		2.78	2.25	2.44	2.61																	2.33							
Mixing & Placing			1.66	1.94			1.79		1.19	1.21	1.04	.87																	3.43							
Setting Forms			.37	.70			.66		.48	.30	.27	.28																	1.42							
Total — Bottom															1.39	1.27	2.38	1.24		.52		.62														
Total — Sides & Arch															5.13	7.46	5.99	7.58		3.38	4.33	4.78		8.63			3.15									
Total — Bottom Sides & Arch	11.03	(7.15)	6.83	7.34	(7.15)	(7.15)	7.26	(5.00)	5.59	4.77	4.59	4.82	(5.50)	(5.50)	6.52	8.73	8.37	8.82	(7.00)	3.90	(7.00)	5.40	(8.50)	(10.00)	6.86	8.01	(7.25)	(7.75)	9.90	(7.75)	(7.75)	5.52	7.65	(9.00)	(9.00)	6.10
Cost of Lining for Past Month per cubic yard Concrete — Cu. Yds. per Ft.	1.80		1.22	1.24			1.22		.93	.91	.67	.94																	1.17 1.01							
Mixture	1-3-7 1-7		1-7	1-7			1-7	Tunnel Floor only	1-3-6	1-3-6	1-3-6	1-3-6		Total to Date		1-2-7						1-5		No. half much broken & disturbed South half undisturbed	1-8				For Past Month 1-6							
Sand, Rock, Gravel	1.05		1.40	1.07			1.08		.74	.89	.73	.89													81				2.96							
Cement	Jan. 1912 1.84		3.02	2.90			2.84		2.49	2.93	3.07	3.40																	1.99							
Mixing & Placing	1.18		1.38	1.41			1.42		1.22	1.51	1.13	.98			3.58					1.74					2.38				2.10							
Setting Forms	.32		.27	.25			.47		0	0	0	0																	.48							
Total	4.39		6.07	5.63			5.81		4.45	5.33	4.93	5.27			6.12	6.72		5.06		4.86				6.30	6.60	5.85	5.12		7.33 8.46				4.58	6.02		
Plastering per Lin. Ft.	incl in Lining	(.96)	.87	.96	(.96)	(.96)	1.04	(.59)	.67	.62	.46	.62	(.59)	(.59)	.34	.31	.35	1.10	(.43)	.48	.22	.21	(.80)	(1.00)	(1.00)	(1.00)	(.75)	(.75)	(.75)	(.75)	(.75)	(.75)	(.75)	(.80)	(.80)	incl in Lining
" " Sq. Ft.			.034	.034			.023		.03	.03	.02				.025	.21	.02	.04		.02	.013	.02														
Adit & Shaft Proportions	.62	.38	.34	.20	.16		.36	.61	.39	.72	2.42	.56														.25		.03								
Approx. Cleaning before Lining		(1.00)			(1.00)	(1.00)		(1.00)					(1.00)	(1.00)					(1.00)		(.30)		(1.25)	(.75)			(.40)	(1.25)		(1.25)	(1.25)			(1.25)	(1.25)	
Incidentals & Minor Equipment	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)	(2.00)
Superintendence		(.11)	.10	.14	(.11)	(.11)	.09	(.07)	.09	.03	.07	.06	(.07)	(.07)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	.20	(.20)	(.20)	(.20)	(.13)	(.13)	.13	(.13)	(.13)	(.13)	(.13)	.12	.16	incl. in above
Engineering (Local)	1.07	.14	.30	.29	.25	.28	.25	.13	.18	.21	.15	.19	.09	.18	.23	.20	.10	.23	.17	.15	.15	.06	.18	.12	.19	.16	.06	.09	.10	.10	.05	.23	.13	.19	.18	
Approx. Local Overhead Charges	(1.21)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
Cost of Finished Tunnel per Ft.	52.99	20.41	23.16	29.15	26.79	27.57	28.53	30.38	35.13	33.25	34.84	30.70	27.33	31.82	24.46	26.93	32.58	35.49	30.47	19.37	22.83	20.65	35.09	48.29	29.20	35.88	19.91	22.09	22.88	25.19	25.90	22.50	34.60	37.94	36.33	17.35

Remarks:
- Above includes cost of Electric Power and amortization of Temporary Power Plants
- Add for general expense at City Headquarters, general Engineering Design, Preliminary Surveys and Bench Levels
- Add for Roads and Trails about $1.00 per foot, variable on different divisions. Add for heavy moveable Plant, Rails, Locomotives, Pumps etc., say $1.50 per ft. here on L. A. Aqueduct, including repeated use and deducting salvage, in addition to minor equipment included above ($2.00)

Above Work was by day labor under exceptionally good management. - In using above for data, allow for Contractor's Profit, Ordinary Managemen nd Adverse Labor Conditions.

Data, Monthly Reports to Chief Engineer

COST OF TUNNELS ON LOS ANGELES AQUEDUCT

Condensed by J.R.F. June, 1912 E. & O. E.

on 80 Headings . 24 Miles of Tunnel in Widely Different Formation			TIMBERING			EXCAVATION and Mucking incl. Trimming to Grade & Cleaning			CONCRETE LINING incl. Plastering				TOTAL
KIND OF ROCK (The most Costly at Top)	Number of Tunnel	Net AREA of Tunnel Cross Section Sq. Ft.	% of Length Timbered	Cost per Timbered Foot	Cost per Excavated Foot	Cu.Yds. per Ft. to Prescribed Line	Cost per Cubic Yard	Cost per Lineal Foot	Cu.Yds. per Ft. Theoretically needed	Cost per Theoretic Cubic Yard	Cost per Lineal Foot	All Other Misc. Costs per Foot	COST per Lineal Foot
Hard Granite. Some Very Hard Syenite	13	58	4	3.13	.14	2.88	8.72	25.07	.71	8.81	6.26	3.66	35.13
Hard Granite	15	"	0			2.85	8.45	24.05	.70	7.36	5.15	5.64	34.84
" "	14	"	4	4.67	.16	2.87	8.29	23.74	.71	7.60	5.39	3.96	33.25
" "	17-A.B	"	5	7.28	.34	2.88	7.69	22.14	.71	8.59	(6.09)	3.25	31.82
" "	16	"	1	4.97	.04	2.86	7.49	21.41	.70	7.78	5.44	3.81	30.70
" "	39	63	48	3.58	1.72	3.38	5.34	18.05	.84	8.85	(7.43)	3.27	30.47
" "	P 2-5	97	3	4.10	.11	4.47	4.99	22.30	.89	10.44	(9.30)	3.38	35.09
Elizabeth Lake Granite; Sound Dry, South; Broken Wet, North	72	88	61	8.74	5.35	4.69	6.75	31.71	1.00	11.03	11.03	4.90	52.99
Hard Granite with a Few Slips	12	58	4	3.58	.14	2.88	7.25	20.84	.71	7.88	(5.59)	3.81	30.38
" " " " "	17	"	7	3.95	.29	2.90	6.14	17.79	.72	8.46	(6.09)	3.16	27.33
Granite, Blocky, Very Wet, Treacherous	35	63	48	4.68	2.25	3.38	5.45	18.41	.84	10.37	8.72	3.20	32.58
" " " " "	38	"	74	5.62	4.18	3.58	5.07	18.06	.91	10.90	9.92	3.33	35.49
Granite, Hard, Blocky	4	58	80	2.54	2.03	3.38	3.89	13.13	.90	9.01	(8.11)	3.52	26.79
Granite, Faulty, Decomposed	8	"	26	5.92	1.53	3.03	4.95	15.00	.76	10.92	8.30	3.70	28.53
Granite with bad flow Carbonic Gas Talcose Slips - Wet Ground	3	"	88	4.12	3.64	3.43	3.96	13.58	.92	9.02	8.30	3.63	29.15
Granite, Faulty, Decomposed	29, 31-33	63	47	2.18	1.02	3.37	4.03	13.57	.84	10.76	9.04	3.30	26.93
" " "	27, 28	"	38	2.73	1.05	3.31	4.00	13.22	.82	8.37	6.86	3.33	24.46
Biotite Granite Oblique bands of Harder Rock than in No. 3	7	58	86	3.39	2.92	3.42	3.85	13.15	.91	8.91	(8.11)	3.39	27.57
Decomposed Granite & Porphyry	43	63	67	.97	.65	3.51	3.34	11.71	.89	8.12	(7.22)	3.25	22.83
Decomposed Granite, Homogeneous	42	"	32	1.28	.41	3.26	3.48	11.33	.80	5.48	4.38	3.25	19.37
Decomposed Granite	46	"	43	2.60	1.13	3.34	3.22	10.75	.83	6.76	5.61	3.16	20.65
Medium Granite	2, 2-A	58	95	3.26	3.10	3.48	2.47	8.62	.93	8.28	7.70	3.74	23.16
Granite, Soft, Broken	1, 1-A.B	"	42	1.87	.78	3.12	2.52	7.89	.80	10.13	(8.11)	3.63	20.41
No. Half - Slate, Hard, Broken, Disturbed So Half - Sound, Cost very much less than No	73	132	86	7.31	6.27	6.58	4.21	27.70	1.27	8.67	(11.00)	3.32	48.29
Slate and Schist	P 10-14	97	79	7.23	5.72	5.17	3.38	17.47	1.10	8.90	(9.80)	3.34	36.33
Quicksand and Caving Ground	104	92	98	5.41	5.29	5.10	3.46	17.65	1.12	7.50	8.40	3.26	34.60
Sandstone	P 8, 9	97	71	7.81	6.55	5.10	3.59	18.28	1.07	9.16	(9.80)	3.31	37.94
Incipient Sandstone, Dry Holds record for Progress, 1063 ft. in 30 days	17-M	79	19	1.56	.29	3.85	2.06	7.96	.83	7.35	(6.10)	3.00	17.35
Compact Sand Gravel and Clay	77	132	70	5.47	3.84	6.48	3.00	19.42	1.23	7.32	9.01	3.61	35.88
" " " "	75, 76	"	40	3.34	1.33	6.23	2.67	16.62	1.14	6.89	7.86	3.39	29.20
" " " "	93	92	78	2.99	2.32	4.92	2.26	11.14	1.06	8.02	(8.50)	3.23	25.19
" " " "	94-96	"	100	3.85	3.85	5.12	2.03	10.37	1.13	7.52	(8.50)	3.18	25.90
" " " "	78, 79	"	3	2.07	.06	4.25	2.03	8.66	.82	9.76	(8.00)	3.19	19.91
" " " "	100-102	"	100	3.62	3.62	5.12	1.80	9.25	1.13	5.55	6.27	3.36	22.50
" " " "	82, 84, 85	"	88	1.60	1.40	5.01	1.78	8.94	1.09	7.80	(8.50)	3.25	22.09
" " " "	89	"	100	1.38	1.38	5.12	1.49	7.62	1.13	9.43	10.65	3.23	22.88

To the Total Cost given in last column, additions must be made for General Expense at City Headquarters, General Engineering Design and Preliminary Surveys and Bench Levels. Also add for Roads and Trails about $1.00 per foot, variable on different Divisions of the Work. Also add for Heavy Moveable Plant - Rails, Locomotives, Pumps, etc. - say $1.50 per ft. here on L. A. Aqueduct, including repeated use and deducting salvage. Minor Equipment, Temporary Power Plants and cost of Electric Power are included in the Tabulated Costs. The work was done by day labor under exceptionally good management. Hence allow for Contractor's Profit, Ordinary Management and Adverse Labor Conditions.

The north half of this Elizabeth tunnel in crossing the broad broken zone beneath a lake, was in a decomposed granite—badly broken, blocky, wet and difficult to support during construction. Substantially all this north half had to be timbered and some of the ground swelled so that it had to be retimbered very heavily two and three times. The natural difficulty is indicated by the fact that two and a half miles was largely excavated by means of a bottom heading driven in advance, with false sets and crown bars to carry the weight of the roof ahead. It was then widened and permanent posts and a temporary floor put in, from which the upper part of the section was then excavated. 96% of this 2.5 miles required timbering to support the rock during construction and for the safety of the workmen, and about 1,000 feet in from the portal a bad flowing mud seam, thirty feet thick, was encountered, which necessitated a shaft put down beyond, to maintain progress while the mud was being drained out and being cautiously passed thru.

The south two and a half miles of the Elizabeth tunnel was in gneissoid granite, hard in some places but rather soft in others, but on the whole presenting favorable conditions for construction and such that only 22% of its length required timbering.

Including the bonus the wages paid on the Los Angeles work were high but the progress was exceptionally great. The men were each paid a bonus of 40 cents per lineal foot for each foot by which the ten-day progress exceeded the assumed normal eight feet per day, the men per shift being limited to a reasonable number. This excess averaged 4.38 feet per day per heading, and thus the bonus amounted to about $1.75 per day per man. This was intended to be an equitable division between the men and the city, half and half, of the saving effected by the extra effort of the men in obtaining a rate of progress greater than the normal for these natural conditions and confidence was established among the workmen that a bonus rate once fixed would never be reduced.

For the total length of about five miles, or a distance of 2.5 miles inward from each portal, and including the delays from the mud seam and shaft above mentioned, they averaged better than eleven feet per day in each heading of the Elizabeth tunnel, and the whole five miles were driven thru in forty months. This fact is of particular interest, since this Los Angeles tunnel is of substantially the same length as the longest of the Hetch Hetchy tunnels between shafts; and it is interesting to also note that near its center or from two to two and a half miles away from the portals the rate of progress and the cost per foot were not any greater than near the entrance. This was rendered possible by the application of modern methods of electric haulage.

The principal data obtained from this Elizabeth tunnel are presented in the foregoing table and in the table next following is a compilation of costs of this and other representative tunnels from the field engineer's monthly reports on the Los Angeles aqueduct, driven in a great variety of formations, but all under exceptionally able engineering supervision, and each cheapened also by a bonus paid the men for excess over normal rate of progress.

The fact that excavating the bad rock of the north half cost so much less than for the good rock of the south half, already commented upon in a footnote, was here in part due to a difference in foremen and the men that they attracted. The one in charge of the north half is said to have been an exceptionally able man, with a strong personal following of able miners.

The final cost (when holed thru and two-thirds lined) stated in the report of July, 1911, including, in addition to the above, equipment, headquarters administration and surveys, but not including any of the cost of lining, was $44.80, but when all is finished this cost per foot will be lessened from sale of equipment.

In general, local administration, sanitation and housing, material handling, water supply, cost approximately $1.21 per lineal foot.

In surroundings, these Los Angeles tunnels were isolated, mostly up in the hills along the edge of the desert, in a country hot in summer and unattractive to workmen, and in the work of tunneling altho they had the advantage of working from adits with an easy dump, as compared with the slower, more expensive hoisting from shafts on most of the Hetch Hetchy line, particularly on the Tesla-Antonio sections, and at the deep shafts near Groveland, this advantage was largely offset by the necessity for a cable hoist or for building a heavy road to the adit, and particularly by the very long haul of the cement used in lining the tunnels.

The Hetch Hetchy aqueduct has decidedly the advantage in being well watered and with more abundant vegetation. Water for all purposes on the Los Angeles line commonly had to be brought a long distance in pipes, and as will be seen from the cost sheet this added materially to their expenses.

Electricity would be distributed all along the San Francisco line for light and power, as it was on the Los Angeles work.

The feature which chiefly controls the cost of a tunnel within the range of sizes needed for various portions between Hetch Hetchy reservoir and the Crystal Springs reservoir, is the quality of the ground. For example, the cost per cubic yard for excavation and mucking was found five times as great in the small 58-foot sections of Los Angeles tunnel No. 13 in very hard granite with syenite, as the cost in the soft sandstone of the 92-foot section of Los Angeles tunnel No. 89. A large section of 132 square feet like Los Angeles tunnel No. 75 should be excavated for a much smaller price per cubic yard, quality of rock being the same, than the small section of 58 square feet used all thru the Jawbone region, because outside a section barely sufficient to give room for the men all of the yardage is blasted out much easier than the heading.

The highest cost per lineal foot was found in the Elizabeth Tunnel No. 72, and its cost per cubic yard was well toward the top.

Condensing and classifying the foregoing table so far as possible in order of difficulty of the ground, we obtain the second table, which can be used as data for the San Francisco tunnels by first making comparison of the quality of rock likely to be encountered and its probable percentage of timbering, with that inspected on the Los Angeles work.

The cost of concrete lining per cubic yard should not differ widely nor should there be a wide difference in the cost per cubic yard for mucking in tunnels of the same length.

Notes on Tables of Tunnel Costs

In the preceding tables of tunnel cost, taken from the monthly reports on the Los Angeles aqueduct, the inclusion of figures in parentheses indicates that these have not been copied directly from the monthly report sheets but have been estimated by J. R. Freeman mainly from auxiliary data presented in their report sheets.

In order to obtain for our purposes a correct estimate of the complete cost of each tunnel when finished, including proportionate share of buildings, tools, equipment, temporary electric power plants, pipe lines and general expense, we have had to make a few assumptions based upon general experience and so our figures for the incidental expenses may differ slightly from their final adjustment by the Chief Engineer. Failure to realize the magnitude of the incidental expenses on work of this character out in the wilderness, is common among both engineers and contractors when making hurried preliminary estimates. Therefore particular care has been taken in the present compilation to include everything at safe figures.

Cost of Lining per Foot

In the case of tunnels not yet lined, the cost of lining per foot has been estimated mainly from what it cost to line other tunnels in the same division. Cost per foot of plastering has been estimated in the same way. In lined tunnels where plastering has not yet been done, it is assumed that it will have to be done later and hence the estimated cost of plastering has been added.

Cost of Cleaning Before Lining

For those tunnels which already have been lined the figure given for the cost of excavation and mucking includes the cost of trimming off projections of rock and cleaning out the loose muck from the bottom, but for the tunnels not yet lined a figure has been added in the table to cover the estimated cost of the final trimming and cleaning.

Superintendence

For those cases in the table where the cost of superintendence was not found included in the monthly reports an allowance has been added.

Local Engineering

This covers chiefly lines, grades and monthly estimates. One reason for this being small is that general accounts for bench levels and re-testing the line are included in the general engineering and designing; another reason is that fewer men sufficed than would have been needed on contract work. Superintendents could be better held responsible for quality.

Incidentals and Minor Equipment

All of the following incidental expenses are distributed into the cost of tunneling given in the table two pages previous, and covered by the general charge of $2.00 per lineal foot, which figure is an approximation deduced as follows:

APPROXIMATE TOTAL COST UP TO JANUARY 31, 1912, OF ITEMS SHOWN IN TABLE.

	Div. 5 & 5a.	Div. 7.	Div. 11.	Total per mile	Total per foot.
Length tunnels	65,800 ft.	65,100 ft.	48,400 ft.		
Concrete or steel siphons	8,600 "	13,700 "	16,000 "		
Covered conduit	44,100 "	38,500 "	11,500 "		
Flumes	—	400 "	—		
Total feet	118,500 ft.	117,700 ft.	75,900 ft.		
Miles	22.4 miles.	22.3 miles.	14.4 miles.		
Pipe lines	$41,700	$82,800	$17,800	$2,400	$ .455
Buildings	72,800	70,800	31,100	2,960	.560
Expended, buildings	900	2,900	2,800	110	.021
Proportion L. D. Phone & M. & O.	10,000	10,000	7,000	460	.086
L. T. power lines	8,700	800	18,800	480	.090
Local telephones	5,200	4,700	3,400	230	.043
Reorganization	4,700	1,900	2,400	150	.029
Miscellaneous losses	4,900	600	1,300	120	.022
Miscellaneous tests	400	10,500	100	180	.035
M'nt'g and operating pipe lines	14,000	18,400	9,500	710	.134
M'nt'g and operating local telephone	2,500	200	1,200	60	.012
M'nt'g and operating roads and trails	5,500	1,800	4,400	200	.037
Proportion of general equipment, less salvage, say	10,000	10,000	7,000	460	.086
Expended, equipment	12,800	9,900	11,300	580	.109
Total incidentals and minor equipment for tunnels, siphons and conduit	$194,100	$225,300	$118,100	$9,100	$1.722

To find approximate proportion applicable to tunnels, distribute above in that proportion which the material and labor cost of tunnels in the division bears to the total cost of the division. This places the burden on the tunnels as follows:

Division 5 and 5-A	$130,000	or $2.00 per foot
Division 7	150,000	or $2.30 per foot
Division 11	83,000	or $1.70 per foot

(For a mean value use $2.00.)

Net Cost of Heavy Moveable Plant

This is the most difficult figure to obtain before the work is closed and a feature wherein different projects may differ widely with the accessibility and character of the country.

The tunnel costs tabulated in the monthly reports from which we have taken our data, "do not include the proportionate share for *buildings, equipment, pipe lines and general expense*," a part of which have already been included by J. R. F. in the $2.00 allowed for incidentals and minor equipment.

It is difficult to separate the part proper to tunnels from that pertaining to cut and cover aqueduct and steel pipe. This proportionate amount per foot on the Los Angeles work is estimated as follows on the basis of distributing it to tunnels and other types of conduit in proportion to their cost as found on typical divisions. This equipment covers air compressors, power drills, mine cars, tunnel railroad material, electric locomotives, ventilation, hoists, pumps and similar heavy apparatus that on a long job like this can be moved from one tunnel to another; and since its upkeep is provided for, can be sold when the work is finished.

Electric Power and Temporary Electric Generating Plants

In the case of the Elizabeth tunnel and the several tunnels of the Saugus Division, no electric power generating plant was installed, power being purchased at meter rates from the commercial lines, which ran near the aqueduct leading to Los Angeles. The cost of this leased power is included in the cost of excavation.

For all the northerly work, including the tunnels of the Little Lake, Grapevine and Jawbone Divisions, small hydro-electric plants were built and long high-tension transmission lines extended to furnish power and light for tunneling, tramming, repair shops, conduit power shovels, concrete mixers and a great variety of work. We understand the cost of this power month by month was distributed into the above costs of excavation at a rate per kilowatt hour that provided for amortization of the plants, although they will remain useful.

Pipe Lines

A vast amount of water piping was required for camp purposes and for mixing concrete and other construction purposes, where the Los Angeles line followed the edge of the desert. This item would be much smaller in the well water country along the line of the Hetch Hetchy aqueduct and is covered in the $2.00 per foot allowed for miscellaneous plant.

Local Overhead Charges

Tunnel costs tabulated in the Los Angeles monthly reports for work done after July 1, 1909, "do not include *division administration*."

A suitable proportionate amount per foot is estimated as follows, from Sheet 27-E in the report for January, 1912, which gives the following total costs of Division Administration to date:

	Division 5a.	Division 7.	Division 11.
Total cost July 1, 1909, to January 31, 1912	$64,780.00	$54,720.00	$59,460.00
Rough approximate total length of aqueduct line built from July 1, 1909, to January 31, 1912	13 miles.	11 miles.	11 miles.
Cost of division administration per foot of aqueduct, including tunnel, conduit and syphon	$ .95	$ .94	$1.02

Use $1.00 per foot as the proportional amount of Local Overhead charges to be added to reported cost of each tunnel which was built after July 1, 1909.

But very little of the tunnel work represented in the table on Los Angeles Cost Data was done before July 1, 1909, therefore we add $1.00 per foot for Local Overhead Charges to the cost of all tunnels shown in the table.

Comparison With Tunnels of Hazen Report Upon Filtered Water From the Sacramento River

The tunnel from filters at Antioch would cross the Mt. Diablo-Mt. Hamilton range a few miles northerly from the route now proposed for the Hetch Hetchy aqueduct and appears to present even more of geological uncertainty.

As a preliminary figure, intended to be very safe and liberal, Mr. Hazen estimated $65.00 per foot for his two tunnels, lined with concrete to an area equivalent to a circle 10 feet in diameter, one 3.4 miles long, the other 8.7 miles, and included some deep shafts at the same price per foot.

Local Conditions near Altamont

The recent railroad tunnels near Altamont, a few miles northerly from our Tesla-Antonio line, are said to have encountered some swelling ground and presented some special difficulties. Our tunnels are deeper under the mountain. The difficulty of "swelling ground" is seldom anything more than a result of the gradual softening or loosening of the ground surrounding the timbering, by the action of percolating water or its slow disintegration from exposure to air. Such troubles come commonly from the desire of contractors to defer concrete lining until the excavation is finished, and, for example, on the Los Angeles work has been largely conquered by following with the concrete lining close behind the excavation. Once well lined with concrete there is no further trouble.

At Tesla much trouble was experienced in the extensive coal mine workings from soft and swelling ground, but our line has now been moved south to avoid these conditions.

Basis of Estimate for Cost of Steel Pipe, San Joaquin Valley

The following estimate has chiefly in view the steel pipe, about forty-five miles in length and seven feet six inches net diameter, to be built under the exceptionally favorable conditions found in crossing the San Joaquin Valley. This pipe is designed to carry the full head and pressure at about 200 pounds per square inch, due to the hydraulic gradient necessary for delivering 200 million gallons daily, or half the ultimate 400 million gallons daily, of water from the Upper Tuolumne by gravity flow into the Crystal Springs reservoir or into Lake Chabot. This cost problem is analyzed into its elements so that the same data may serve for a different diameter and thickness if an extra allowance is made for differences in local conditions.

There is such a great amount of this pipe required for the San Joaquin line and the Bay Head line that an exceptional opportunity is given for perfecting labor saving methods.

The Type of Steel Pipe Proposed for Crossing the San Joaquin Valley

It is proposed to use a soft and ductile, open-hearth steel of the so-called "flange" class. A cheaper steel might serve, but it is considered desirable to have a high degree of softness and ductility in order that the plates may stretch rather than crack in case of unusual strains due to water-hammer or settlement of the ground, abuse in forcing fits during construction, or in case of an accident such as has occurred where under a sudden rainfall a partially completed pipe has been floated from its seat. Also after completion, in case of a washout, it is desirable to have a soft and ductile steel.

The old-fashioned wrought iron in Eastern practice certainly has resisted rust much better than modern steel. I have made several careful inspections of large wrought iron penstocks ⅜-inch thick and 9 feet diameter, that have been in daily use for supplying water to turbines at the factories of Lowell and Lawrence now for more than sixty years, and there is every reason to believe they will continue in tolerable condition for a full century, but steel is cheaper and more readily obtained, is stronger and tougher and it can be protected against rust by various means. Steel is being used on all the great pipe siphons of the New York aqueduct, on those of the Los Angeles aqueduct, and in the smaller aqueducts recently built by Springfield, Mass., Portland Ore., Pittsburgh, Penn., etc., and has been used instead of wrought iron for the pressure pipes on all of the recent great water power developments in California and the world over.

The steel proposed would have an elastic limit of about 30,000 pounds per square inch, with an elongation of 25 per cent when tested in a specimen eight inches long. Its ultimate strength would average about 60,000 pounds per square inch and the working stress to be imposed on the gross cross-section where the head is greatest would be not far from 12,500 pounds per square inch, but not exceeding 15,000 pounds on the net section if a riveted joint is used

The method of joining the sheets for the longitudinal seams would be probably by the bar-lock method or something similar, because this gives the maximum efficiency and the minimum weight of steel pipe for resisting a given bursting pressure; but since these plates are thicker and the pipe of larger diameter than heretofore constructed with that type of joint, the present estimate for the larger and thicker pipes is worked upon the basis of a triple-riveted butt joint, with two cover plates

Rust-Proofing

In view of the great length of this Hetch Hetchy pipe and the high pressure upon it, it is desirable to keep the diameter small as practicable for the required carrying capacity and it is therefore necessary to obtain a smooth interior, and one which will remain smooth for an indefinitely long period.

In view of the trouble that has been experienced in several large modern steel pipes from corrosion, tuberculation and pine-hole leakage and pitting after ten or fifteen years of use, notwithstanding the application of various paints, asphalts and baked "enamels," it is of great importance to provide the most efficient safeguard against internal roughness and against perforation and leakage.

There is good ground for the belief of the Chief Engineer of the Los Angeles works that steel pipes rust less under California conditions than in the Eastern states, and that in general the slightly alkaline character of these waters, as compared with Eastern waters, made very slightly acid by the admixture of water from swamps, presents a much smaller tendency to corrode. Nevertheless, to be on the safe side as regards smoothness, permanence and cost, I have provided for more elaborate treatment than has yet been used on any large aqueduct pipes East or West, save those recently built for New York.

Cement Lining

Altho special steels are now offered in the market at a slightly increased price which promise much better results in withstanding rust than the ordinary commercial article, it is believed that the important matters of permanent smoothness and resistance to corrosion can in the present state of the art be safeguarded most economically and most surely by covering the steel with a thick coating of rich Portland cement mortar or concrete. All of the many miles of large steel siphons now under construction for the additional water supply of New York City are being thus protected inside and outside and a somewhat similar coating has efficiently protected the small thin wrought iron street mains of Plymouth, Mass. (for example), for forty years.

Also the use of this plastic material makes it possible to obtain a smooth interior irrespective of projecting rivet joints and edges of plates and thus permits adopting the simplest and cheapest structural methods.

In addition to promising longer life for the steel conduit the cement lining must be credited with giving a much larger water-carrying capacity than the riveted lap joint pipe of thick plates, which is certain to have its roughness of interior surface materially increased in course of a few years by some such tuberculation as I have personally noted in various California pipes, notwithstanding the tubercles will be much smaller than with Eastern waters. There is abundant experimental evidence from which one may deduce that a pipe seven feet in diameter, smoothly lined with cement will after some years under equal slopes carry as much water as a pipe eight feet in diameter made in the ordinary manner; and with the saving in circumference of plate comes also a saving of one-eighth part in the thickness of plate required for our high heads

The present estimate, therefore, includes the cost of lining the pipe with a coating of rich Portland cement mortar about one and one-half inches in thickness, which is to be secured against shrinkage and settlement cracks by the insertion of a thin reinforcement of steel-wire netting. This cement lining may be applied in various ways—by the ordinary house plasterer's method, by the "cement gun," by grouting around forms as for the New York pipes; or perhaps by special apparatus, acting in a method somewhat similar to that which was used in lining hundreds and perhaps thousands of miles of small-size thin sheet iron pipe when the cement-lined thin iron pipe was popular thirty or forty years ago, prior to the great drop in the price of cast iron pipe.

For all ordinary conditions in dry ground, in view of the abundant proofs of the durability of pipe exteriors on many old mining pipes under the dry California climate, and the fact that about 90 per cent of this particular pipe will lie along the semi-arid surface of the San Joaquin Valley, the exterior of the pipe would not be coated with cement but would simply be thoroly painted several coats, as on the Los Angeles work and as is common for hydro-electric structures.

The tendency of a thin pipe of circular cross-section to flatten under its own weight when empty, into a slightly elliptical form, will be resisted during the process of placing and bedding and until the cement lining is inserted, by means of stulls or vertical wooden posts, tightly wedged or driven into place. Probably in a pipe of the superior rigidity given by this particular combination of thickness and diameter, it will be found practicable to effectually prevent all trouble from the tendency to crack the cement lining when the water pressure restores the flattened pipe to the circular form, thru compensating for the tendency to flatten by means of a preliminary slight vertical distortion by a line of hydraulic jacks sufficient to give a permanent set to the metal so that it will stand horizontally in circular form when empty.

Special Protection Over Swampy Ground

For the exterior of the pipe where it crosses wet or swampy land, the bottom half is planned to be encased in a bed of rich concrete made from small gravel and having a minimum thickness of nearly four inches, poured in a plastic condition thru channels, or "gates" as a foundry-man would term them, carefully designed to exclude dirt and air bubbles while pouring. The top half of the steel pipe is planned to be covered by hand with a stiffer mortar, varying in thickness from four inches at the mid-depth to two inches at the top and having a "chicken-wire reinforcement."

The ground between the cradles would be carefully trimmed to give a 4-inch space, with a small cross trench for access in riveting the field joint, midway between the cradles, in which the "gate" for pouring the concrete bed would be set.

Also for that portion in wet or marshy ground, this estimate assumes that the pipe will be supported by rigid cradles of reinforced concrete, having a cross-section about two feet square, placed twenty feet apart and extending up to nearly the mid-depth, these cradles being built in place accurately to location and form, well in advance of the laying of the pipe.

Data for Costs

It is always most satisfactory in making such an estimate to select data from recent constructions made near to the work in question, and under conditions of operation which are fully as difficult. We are fortunate in the present instance in having data furnished by William Mulholland, Chief Engineer of the Los Angeles aqueduct, which presents the actual costs under California conditions during the past year for similar work upon steel pipes of larger diameter and laid under more difficult surroundings.

The figures given in the following tables present averages for substantially all of the work completed upon steel pipe siphons for the Los Angeles aqueduct up to January, 1912.

ANALYSIS OF COST OF STEEL PIPE SIPHONS ON THE LOS ANGELES AQUEDUCT.

From the Chief Engineer's Cost Analysis Sheets of January, 1912.

LOCATION.	Nine Mile Canyon.		No Name Canyon.		Dead Man Canyon.		Soledad Canyon.		Quigley Canyon.		Placerita Canyon.	
Length	1,415 feet.		2,016 feet.		3,352 feet.		8,040 feet.		611 feet.		1,572 feet.	
Diameter	9.5 "		9.25 "		11 "		10 and 11 "		11 "		11 "	
Maximum thickness	5/16 inch.		9/16 inch.		½ inch.		½ inch.		¼ inch.		¼ inch.	
Minimum thickness	¼ "		¼ "		¼ "		¼ "					
Average pounds per lineal foot	358 lbs.		478 lbs.		622 lbs.		557 lbs.		382 lbs.		402 lbs.	
Steel Pipe Costs.	Per foot.	Per 100 lbs.	Per foot.	Per 100 lbs.	Per foot.	Per 100 lbs.	Per foot.	Per 100 lbs.	Per foot.	Per 100 lbs.	Per foot.	Per 100 lbs.
Excavation	(On piers.)		$ 1.23		$ 1.02		$ 1.06				$ 1.96	
Steel, rolled, punched; delivered at railroad siding	$10.83	$3.03	13.52	$2.83	15.25	$2.45	13.71	$2.46	$9.56	$2.50	10.04	$2.50
Loading and unloading	.68	.19	1.05	.19	.64	.10	.49	.09	.32	.06	.34	.08
Wagon haul	.27	.07										
Placing	1.43	.40	2.27	* .41	2.94	.44	2.91	.43				
Riveting	1.46	.41	2.36	.41	2.10	.28	2.22	.29				
Calking	.22	.06	.25	.03	—	—	.38	.05				
Painting	.76	.21	.32	.06	—	—	.19	.03				
Timber supports	.97	.27										
Equipment and tools	3.05	.86	3.18	.67	1.11	.18	1.54	.28				
Superintendence	.89	.25	.80	.14	.15	.02	.19	.03				
Engineering, local	.17	.05	.18	.03	.08	.01	.15	.02				
Wells and pumping	—	—	—	—	—	—	1.60					
	$20.73	$5.80	$25.16	$4.77	$23.29	†$3.48	$24.44	$3.68				
Salvage on equipment, tools and timber	1.00	.28	.80	.17	.28	.04	.38	‡ .07				
Total cost of pipe, exclusive of piers, back-fill and blow-off	$19.73	$5.52	$24.36	$4.60	$23.01	$3.44	$24.06	$3.61				
Cost of riveting, per rivet	$ .036		$ .07		$ .07		$ .078					

*Placing steel includes timber supports. †Excluding paint, calking, etc. ‡Exclusive of well and pumping.

Cost of Two Pipes Built by Contract

The cost of the Dove Creek and San Antonio pipes built under contract may be of interest showing certain added costs.

	Nine feet diameter, ¼ inch thick; total length about 1,727 feet.	
	Per foot.	Per pound.
Freight (paid by city)	$2.96	$ .0098
Electric power (paid by city)	.67	.0022
Equipment expense (paid by city)	.75 net.	.0025
Painting (paid by city)	.30	.0010
Inspection (paid by city)	.01	
Additional to contract, total	$ 4.69	$ .0155
As per contract for furnishing and erecting pipe, also furnishing erecting equipment	12.92	.0426
Total for pipe completed	$17.61	$ .0581

The total tons in all six of the above pipes was only about 4,000 tons, whereas the tonnage in the line across the valley will be upward of 90,000 tons, and in plates more than twice as thick, which lessens relative cost per pound of perforating, etc.

General Type of Los Angeles Pipes

All were made up from basic open-hearth steel, with a single sheet long enough to make a complete ring. These sheets were punched, bent to circle and nested for shipment in nests of three full sheets to a nest, riveted to form a ring after hauling to the site and then transported one ring at a time to the point of use. All was painted inside and out two coats or four coats in all, with water gas tar, obtained from the Los Angeles Gas Works.

The steel specification called for 60,000 lbs. ultimate tensile strength, for standing without fracture a cold bend to 180° flat. Rivet steel ultimate tensile strength 50,000 lbs. per square inch.

Cost of Steel Delivered

Considering the elements of costs of steel pipe in detail, the matter of first importance is the cost of the steel, perforated for riveting, delivered on cars or boat near the site of the work.

In arriving at the cost of the steel delivered it is necessary to consider the superior access to the San Joaquin Valley line, the ground "level as the floor of a house," the four lines of railroad which cross this part of the aqueduct line, the possibility of water competition via the San Joaquin River, and the fact that the Panama Canal will be opened before this steel will be needed and that there will then surely be a reduction in the present freight rate, which is about three-fourths of a cent per pound overland by railroad. Considering the recent rate for large quantities of $10 per ton or one-half cent per pound by sea and rail, via the Isthmus of Tehuantepec, a freight cost from the Eastern seaboard to San Francisco Bay of 40 cents per 100 pounds is probable for freight contracts aggregating for the single line of the San Joaquin and Bay Head crossings 115,000 tons, or $920,000.

Response of steel manufacturers to recent inquiry shows that plates of the large size and thickness required for the pipe across the San Joaquin Valley could be placed now at 1.35 cents per pound for plates at Pittsburgh; adding 40 cents per 100 pounds for ocean freight gives 1.75 cents per pound. A price of $2.00 per 100 pounds would leave 0.25 cents for perforating 3.70 rivet holes per 100 pounds of shell and cover plates (of which only 1.33 holes per 100 pounds would be reamed), and for freight from rolling mill to the seaboard. (The holes for the longitudinal seam in the shell plates would be punched small and reamed out to size, the holes for the round-about seam simply punched.)

As one practical guide we have the following recent cost figures from the Los Angeles pipes giving cost of steel per 100 pounds, bent, punched and delivered on cars near the work.

Name.	Cost of steel per 100 lbs.	Location.
Nine Mile Canyon.	$3 03	Nearly 60 miles northerly from Mojave, on new line of S. P. R. R., with high local freight rates.
No Name Canyon.	2.83	
Deadman Canyon .	2.45	About 30 miles northerly from Los Angeles.
Soledad Canyon...	2.46	About 30 miles northerly from Los Angeles.
Quigley Canyon...	2.50	About 30 miles northerly from Los Angeles.
Placerita Canyon..	2.50	About 30 miles northerly from Los Angeles.

The figure adopted in this estimate for the cost of steel, with rivet holes punched and drilled, delivered at a field shop on the aqueduct line, per 100 pounds is $2.00.

Wagon Haul, Loading and Unloading

We have the following data from the Los Angeles work, the first two examples being for a haul from the edge of the Mojave Desert into the foothills, and the later examples being in the rough and hilly country near Newhall, about thirty-five miles northwesterly from Los Angeles.

Name of Canyon.	Approximate miles from railroad in air line.	Diameter of finished pipe, feet.	Average weight per lineal foot, pounds.	Total length of pipe, feet.	Cost of loading, wagon haul, and unloading.		Remarks.
					Per foot.	Per 100 lbs.	
Nine Mile .	3	9.5	360	1,415	$ .95	$ .26	A desert road and a hard climb.
No Name .	3	9.25	475	2,016	1.05	.19	
Deadman ..	3	11.	622	3,352	.64	.10	In the foothills nearer sea level, nearer Los Angeles.
Soledad ..	—	10 & 11	558	8.040	.49	.09	
Quigley ...	3	11.	383	611	.32	.06	
Placerita ..	2	11.	400	1,572	.34	.08	

Comparing the above with conditions in the San Joaquin Valley, the country is here far more smooth and much better for hauling. The fact that the plates are for a pipe of less diameter than those in the above table, altho of double the thickness, will tend to lessen the cost of handling and hauling per pound, for there will only be about half as many pieces to be handled. Upon studying the map as to distances from the four lines of railroad which cross the Hetch Hetchy pipe line and the general character of the country it appears that the average length of haul from railroad will be between three and four miles and, in general, very heavy loads can be hauled. Forage for teams will be cheap and all conditions favorable for low costs.

Therefore it appears safe to adopt 10 cents per 100 pounds, which is above the average of the Los Angeles figures for the Saugus Division. For a majority of our pipe across the San Joaquin Valley, which with a single triple-riveted joint and its heavy cover plates will average weighing about 860 pounds per lineal foot, this amounts to 86c per lineal foot of pipe, or to $4,540 per mile.

One needs to go over this San Joaquin line to fully appreciate how favorable it is for hauling and placing.

The loading at the field shop on to the wagon would be done by a locomotive crane and the unloading performed by the same crane which places the sections of pipe in the trench. The long continuous lines of the San Joaquin and Bay Head crossings permit labor-saving appliances that would be out of place in the canyons or in placing the steel pipes of a water power plant. (In the latest practice on the Los Angeles work, where the road was smooth each length of pipe was itself temporarily converted into a sort of giant wheel or road roller, by inserting a temporary axle, held within crude temporary spokes, bolted into the ends of the pipe and then by means of a mule team hitched to a chain attached to the two ends of this axle, the whole was rapidly trundled along.)

The hauling of the San Joaquin and Bay Head pipes would be mostly done along a new and nearly level road to be built on the right of way for the pipe line, the cost of which road is figured separately. In order to lessen the haul, probably two cheap field shops for bending, riveting and calking would be built simultaneously at different railroad crossings and these shops would be moved once or twice as the work progressed. The only heavy special tools in these shops would be a set of bending rolls, a riveting machine and a locomotive crane, and these would be combined with the ordinary repair shop outfit for mending tools.

Recent quotations on similar tools for shipyard work were:

Bending rolls, electric driven, 15 in. diam. x 12 ft. long, for ¾-in. plates, including jib crane........................	$5,000 erected.
Riveting machine, hydraulic, 13 ft gap, including piping....	5,500 "
Electric gantry to handle sections during riveting.........	5,000 "
Pump and accumulator for 1,500 lbs. per sq. in................	4,000 "

To which should be added about $16.00 per ton for rail freight to California.

So it is seen one or two field shops are not formidable affairs on steel pipe work aggregating nearly forty-five miles and costing about....... ....
for the San Joaquin crossing alone about..... ... . $6,282,000

Placing

We have the following data from Los Angeles:

Name of Canyon.	Diam. of pipe, feet.	Cost of placing, per lineal foot.	Weight of pipe, per lineal foot.	Cost of placing, per 100 lbs.	Remarks.
Nine Mile.....	9.5	$1.43	360	$ .40	Used cableway 1,435 feet long, 178 feet drop.
No Name	9.25	2.27	475	.41	
Deadman	11.	2.94	622	.44	
Soledad	10 & 11	2 91	558	.43	

Placing the sections of pipe already bent and riveted along the level floor of the San Joaquin Valley is a far simpler matter than placing sheets and single rings of pipe on the steep sides and deep bottoms of the above canyons; nor will it require any such expensive equipment as the cableway used in the examples above given. Some simple device can be used, like a strong locomotive crane on a broad wagon wheel base, which will travel on the level valley floor along with the work and swing the pieces accurately into place. The fact that the Hetch Hetchy pipe is twice as thick and that its weight per lineal foot averages about 50 per cent greater than for the pipes in the above table should also tend to lessen the cost per pound.

Considering the exceptionally favorable surroundings it appears that a fair figure for handling and placing the sheets or rings and for inserting the end joints all ready for the final riveting in the field will be as follows:

Inquiry shows that plates up to more than ten feet in width and up to fully 24.4 feet in length, ¾ inch thick, required for forming the rings of this pipe across the San Joaquin Valley can be obtained from several of the large modern plate mills.

These plates would be perforated for riveting at the rolling mill, oiled thoroly, shipped flat to the field shops on the line of the aqueduct, where bending rolls and a hydraulic riveting machine would be set up (or they could be bent and shipped nested as for the Los Angeles work). The completed ring, with longitudinal seam all riveted would be hauled by wagon (or trundled as on the later Los Angeles work) to its place or possibly two or three rings would be joined and riveted at the shop into a section, if hauled on a wagon, ready to be placed as one piece, thus lessening the field rivets and hastening progress. This would materially lessen the cost of placing.

This cost of placing will be estimated at $1.29 per lineal foot, or per 100 lbs. $0.15.

Each ring if 10 feet long with single seam will weigh 8,600 pounds, or about 4.3 tons, and the allowance, exclusive of wagon haul for taking this single ring off the wagon and placing it in the trench, slipping its end over or into the preceding ring, is thus $12.90; or if two rings are joined the cost allowed per 20-foot section, weighing 8.6 tons is $25.80.

This figure is liberal enough to also cover setting the rings as already described, into a shape that would compensate for tendency to distort when horizontal and empty (which work would probably be done at the shop), and will also cover inserting the stulls or braces, the precise adjustment of position in the trench and the forcing the ends together by means of hydraulic jacks, and the field riveting.

Riveting

In the case of the Los Angeles pipe siphons we have the following data:

Name of Canyon.	Diam. of pipe, feet.	Av. thickness of plate, inches, approximately.	Price per rivet.	Total length in feet.	Cost per lineal foot.	Av. weight of pipe per lineal foot, pounds.	Cost of riveting, per 100 lbs., of pipe.	Approx. No. of rivets per lineal foot of pipe.
Nine Mile .	9.5	¼	$ .036	1,415	$1.46	360	$ .41	40
No Name ..	9.25	⅜	.07	2,016	2.36	475	.41	35
Deadman ..	11.	⅜	.07	3,352	2.10	622	.28	30
Soledad . .	10 & 11	—	.078	8,040	2.22	558	.29	29

The parallel between the Los Angeles siphons and the San Joaquin Valley pipe in this matter of riveting is not very close, because of the much greater pressure which the Hetch Hetchy pipe has to stand, and its greater thickness. Moreover, the great length of this pipe and the opportunity to effect economies by means of experimental study makes it premature to now attempt to specify the precise details of the joint that will give the maximum economy when corrosion of plate during the next half century is also considered. It is possible that instead of a riveted joint, some modified form of lock-bar will be actually used. The absence of vibration and the slow change in stress makes the friction of the joint an element worthy of consideration, and because of the great pressure and the rigidity of the plates, it will be best to avoid field riveting on the longitudinal seams and to rivet by hydraulic pressure in a field shop as already suggested.

When the time comes to build the pipe it will be true economy to test to destruction by internal water pressure the joints in some full-size sections of pipe, say, twenty or thirty feet in length, made up in several ways, for the plates will not be wasted as the joints can be patched and the pipe can be used afterward at places where the pressure is lighter.

For present purposes, for this steel pipe 7 feet 9 inches inside diameter and about ¾ inch thick, assume that the longitudinal seam will be made with the expensive triple-riveted butt point with two cover plates, the same form of joint that is now being used by the New York Board of Water Supply on its largest steel pipe siphons, with rivet holes about 1¼ inches in diameter, spaced about 5 inches and with an inner cover 13 inches wide and outer cover 20.5 inches wide. This form of triple-riveting gives about 88% theoretic efficiency, weakens from rust much less rapidly than the shell and has about 12 rivets per foot of longitudinal seam. On the round-about seam, no rivets at all are strictly necessary, save possibly for preventing cracks in the cement lining at the joint in case of slight slip under the temperature stresses, and an apparatus could be worked out by which the sections tightly fitted would be pulled together under great pressure, forming a friction joint similar to that now used on the pipes of from three to four feet in diameter by the Spring Valley Water Company; but for present purposes assume that rivets of the same size are spaced in a single row about six inches apart, which will call for about 50 rivets around the seam, and if the pipe sheets are eight feet in width, this round seam will add six rivets per lineal foot of pipe, making in all 18 1¼-inch rivets per lineal foot or with sheets ten feet wide, there would be 17 rivets in all per foot.

In view of the size of these rivets and the advantages of hydraulic riveting in strength and tightness, it is proposed to provide one or two field shops at the points where the railroads cross the aqueduct line and to provide in each the required heavy apparatus for bending the flat plates into rings and for hydraulic riveting, and for making up the pipe in sections. The shop would be moved from one railroad crossing to another in order to lessen the wagon haul. The cost of this bending and riveting, including all plant charges and shop maintenance is assumed at $2.00 per lineal foot of pipe or $20.00 for a ring of pipe ten feet long.

This is equivalent per 100 pounds to $0.232, or about 12 cents for each 1¼-inch rivet, which appears very liberal in view of the Los Angeles costs and the superior facilities found on the San Joaquin line.

Calking

In the Los Angeles case the costs of calking were as follows:

Nine Mile Canyon	$0.22 per lineal foot;	$0.06 per 100 pounds.
No Name Canyon	.25 " " "	.03 " " "
Soledad Canyon	.38 " " "	.05 " " "

Considering that in the present case it is planned to coat the pipes inside with cement, calking is a matter of minor importance. The thin sheet iron cement-lined pipe which was much used many years ago was not very much thicker than stove pipe, had slip joints at the ends and had longitudinal seams which depended wholly upon the lining of cement mortar for tightness, and altho their cement coating was less than half as thick as that proposed for this pipe, these old pipes commonly proved tight until the defects of workmanship resulting from failure to completely cover the metal with cement permitted holes to rust thru the thin pipe. Calking is so cheap, the pressure so great and the tightness of this aqueduct of such importance that as a matter of insurance and of extra precaution it will be well to calk everything most thoroly, first inside and outside at the shop and again in place after the riveting of the field joint.

The length of seam per lineal foot will be less than for the Los Angeles pipes and the facilities for using pneumatic calking tools much better, since most of the work will be done in the field shop, therefore add for calking 35c per lineal foot of pipe, equivalent to $2.80 for an eight-foot length, or $3.50 for a ring 10 feet long. This converted to the pound basis, upon the average weight of 860 pounds per lineal foot with one longitudinal seam, gives for cost of calking per 100 pounds. .$0.04.

Painting, or Removing Scale and Rust

In the case of the Los Angeles siphons the costs of painting in the field were as follows. This painting was the sole reliance against corrosion and decreased carrying capacity in the distant future, due rusting and tuberculation, for the Los Angeles pipes altho of steel had no cement lining:

Name of Canyon	Internal Diameter Feet.	Per Lineal Foot.	Per Square Foot-of Plate (Outside Only)	Per 100 lbs. of Pipe.
Nine Mile*	9.5	$0.76	2.5c	$0.21*
No Name	9.25	.32	1.1c	.06
Soledad	10 & 11	.19	about .6c	.03

*Since the above covered inside and outside two coats each, the cost per square foot of surface painted two coats was 1.3c.

The paint used was water gas tar from the Los Angeles gas works.

The San Joaquin Valley pipe presents only about three-fourths as much surface because of its smaller circumference; moreover, because of being twice as thick, its surface per 100 pounds of metal is less than half, wherefore its cost of painting per lineal foot should average only three-fourths of the above, and its cost of painting per 100 pounds should be less than half that in the table above, if it depended solely on paint for protection against rust.

But in the case of the San Joaquin pipe, lining it with Portland cement mortar 1½ inches thick inside the small ring and 2¼ inches thick inside the large ring, and covering with concrete whatever pipe is bedded on wet ground, all serves the same purpose as painting and therefore should lessen the cost of painting. Since before applying the cement it may become desirable to remove mill scale by pickling in weak acid or by sand blast, and since the outside of all pipe not on marshy ground will require the best of painting, or say with a first coat of red lead and linseed oil and a second coat of thick asphalt paint over this, a figure will be adopted about double the average Los Angeles cost per square foot to cover all painting and any pickling.

The external surface of the pipe crossing the San Joaquin Valley is 24.5 square feet. This at 25 c per square foot of plate, which was much the highest of the above figures, gives 62c per lineal foot for the inside and outside. For the average condition on the pipe across the San Joaquin Valley, call it 69 cents. This gives for 860 pounds per foot, a cost per 100 pounds of..............................$0.08.

The ordinary cost of painting structural steel work is about 10 cents per 100 pounds, but on these broad smooth continuous surfaces the cost of labor should surely be less and the cost of the paint proposed—gas tar—will be less.

Construction Plant and Temporary Supports

In some cases of the Los Angeles pipe siphons timber supports were required at the bottom, and in other cases the pipe was supported across the floor of the valley upon deep and strong piers of concrete mansonry, which will have no counterpart in the present case, save perhaps for a short distance near the San Joaquin River. The costs of equipment for the work of building these siphon pipes across the canyons in the Los Angeles acqueduct is of interest, although obviously these relatively short lengths of canyon crossings and the problem of placing the pipe on the steep slope of the canyon and for crossing the stream bed in the bottom of each canyon, all call for much more extensive equipment than will be necessary for assembling, riveting and placing the proposed continuous pipe across the level floor of the San Joaquin Valley.

The Los Angeles costs were as follows, after allowing 25 per cent salvage on the equipment:

Nine Mile..............	$2.05	per lineal foot;	$0.58	per 100 pounds.
No Name..............	2.38	" " "	.50	" " "
Dead Man.............	.83	" " "	.14	" " "
Soledad	1.16	" " "	.21	" " "

In the case of the San Joaquin crossing the total length is about forty-five miles of continuous pipe under the most favorable conditions imaginable, and the same equipment will be used over and over again, for mile after mile. An allowance for use and depreciation of plant, including the two field shops, all cranes, special wagons, etc., of $1.00 per lineal foot, appears very ample, and will amount to $232,000 for the entire 44 miles of the San Joaquin pipe. The same plant could be used for the Bay Head pipe.

This $1.00 per foot for the general weight of 860 pounds per lineal foot of the San Joaquin crossing is equivalent to 11.6c per 100 pounds, or, say, $0.12.

Local Engineering Cost

Engineering, which in the Los Angeles cost sheets presumably means local surveying and the supervision of the Resident Engineer during the difficult placing of the pipe, cost on the first four canyons for the Los Angeles work for the above pipe siphons, respectively, 17c, 18c, 8c and 15c per lineal foot, but obviously this cost would amount to much more on a steep canyon crossing than for the long, straight level valley crossing.

For the San Joaquin crossing $1,000 per mile, or 19 cents per lineal foot, is adopted, principally to cover a critical inspection service, equivalent per 100 pounds to $0.02.

Totals for Steel Work

The following is a summary of the preceding figures and presents the total cost of steel pipe erected complete in place, exclusive of excavation, backfilling and lining and covering with Portland cement concrete, exclusive also of cradle, and not including special structures at the swamp lands near the river or where crossing the irrigation canals.

SUMMARY, STEEL PIPE COST. FOR STEEL ONLY.

For pipe ¾ inch thick, 7 feet 9 inches inside diameter, under the very favorable conditions of the San Joaquin Valley.	Cost per lineal foot.	Cost per 100 pounds.
Steel (via Panama Canal), perforated and delivered on cars near aqueduct, the sheets being large enough to make the rings with only one longitudinal seam, 860 pounds per foot............	$17.20	$2.00
Hauling by wagon, including loading............	.86	.10
Placing	1.29	.15
Riveting (hydraulic on longitudinal seams).......	2.00	.23
Calking	.35	.04
Painting and surface cleaning, inside and out......	.69	.08
Equipment, net, after salvage..................	1.00	.12
Engineering (surveying and local supervision only).	.19	.02
For steel work only, pipe 7 feet 6 inches net diameter, ¾ inch thick, across San Joaquin Valley; total cost if made with one longitudinal seam and triple riveting	$23.58	$2.74

Note that the above figure is the minimum or base cost, under exceptionally favorable conditions, and does not include contractor's profit, overhead costs for management, etc., nor does it allow for inefficient management or bad labor conditions.

Total Costs

The best price for steel pipes erected on the Los Angeles works was obtained on the long siphons of the Soledad and Dead Man Canyons and averaged net for the above items, per 100 pounds of steel pipe complete, $3.55, but that work was done in a much rougher country, with steel costing 55 cents per 100 pounds more than is assumed above. There has never yet been a large steel pipe laid under conditions so favorable for low construction cost as those on this San Joaquin Valley crossing.

The question of profit to the contractor was not included in the Los Angeles case because that work was done without contracts, by day labor under the aqueduct engineers, and the matter of local labor conditions, which may add seriously to the San Francisco cost, will be discussed later.

Excavation and Backfill

Conditions across the San Joaquin Valley are exceptionally favorable, the ground is level without ledge or boulders and is chiefly old wheat fields. It can be worked by plows and scrapers and presents simple and ideal conditions for a light steam shovel or electric shovel, such as was used on much of the Los Angeles aqueduct.

The estimate assumes that the bottom of the steel is to rest six feet deep below the natural surface; that the excavation will be roughed out nearly to the finished size by scrapers or by the shovel and trimmed carefully by hand to the final shape. The cost of excavation by a power shovel would be less than common, because there is no delay of waiting for cars to be "spotted" into position, and the ground is all mellow. It is simply dip, lift, swing and drop on the side opposite that on which the pipe is delivered, ready to be scraped back for the backfill, and all with ground so level that there is no important variation from the ideal section. One must go over the line or at least visit this valley to appreciate the ideal condition for cheap and rapid pipe laying for nine-tenths of the line.

For the relatively short portions in wet ground where pipe is to be bedded in concrete to prevent rust, the concrete for cradles will be poured into ditches, cut about two feet square, the top added and moulded to fit the shape of the pipe by means of a movable form, and after these concrete cradles have hardened, their top surfaces will serve as a guide for trimming the eighteen feet of ditch between the cradles very accurately to the semi-cylindrical form, so as to leave precisely four inches between the steel shell and the earth. After the pipe has been placed, this space will be filled with concrete, poured in a soft condition thru a pipe having its outlet at the bottom of the trench midway between the cradles, made for inserting the field rivets in the bottom of the shell. Pouring it thus will tend to avoid mixing dirt and air bubbles with the concrete. This cross ditch midway between the cradles will also serve both for pumping and as the channel for pouring the concrete.

Some extra precaution or preparation of the earth surface for receiving the concrete may be needed where ground is temporarily so dry as to absorb water from the fresh concrete, or wherever quicksand or flowing mud is encountered, but an inspection of the ground shows that even close to the San Joaquin the length of wet or soft ground is relatively very small and that a good foundation exists for the pipe.

The short length of steel pipe crossing the San Joaquin River will be somewhat thicker and laid in a dredged channel, subsequently refilled, mainly with concrete, and the extra cost of this section is covered by a special estimate.

Exposed Pipe on Concrete Piers

Perhaps it may prove best to construct a relatively short portion of the pipe which crosses the marsh and the river bottoms, on top of concrete piers and leave the pipe uncovered, as has been done on a considerable portion of the Los Angeles steel pipes, where they cross the level floors of the valleys. The pipe itself, of this thickness, forms a safe tubular bridge, and its life would be prolonged indefinitely if occasionally repainted. There can be no question that this method of support would have various advantages for the Bay Head pipe where it crosses the salt marsh and where piers could be cheaply built by depositing concrete within tubular shells sunk to hard stratum of clay.

Computing the girder strength of this 7 ft. 9 inch pipe ¾ inch thick filled with water shows that by double rivetting the round seam with 1¼-inch rivets 6 inches on centers each line and rivet-shear stress of 10,000 lbs. per square inch. This as continuous tubular girder could span 100 feet. Practically a shorter span would be given—perhaps 80 feet in the clear.

Some examples of the cost of piers for pipe supports on the Los Angeles pipes are of interest.

Location—Name of Canyon.	Excavation.	Concrete.	Forms.	Total Cost.
Per Pier—				
Nine Mile	$25.06	$76.02	$31.47	$132.55
Deadman	7.43	81.15	38.34	126.92
Soledad	27.77	70.77	20.91	119.45
Quigley	4.22	71.20	13.07	88.49
Placerita	6.86	41.14	9.53	57.53
Per Cubic Yard—				
Nine Mile	—	7.76	3.21	* 10.97
Deadman	.60	4.16	1.97	6.13
Soledad	—	3.18	1.03	* 4.21
Quigley	.47	3.39	.62	4.01
Placerita	.47	2.14	.50	2.64

* Excluding excavation.

Cost of Excavation and Backfill

The quantity to be excavated to the theoretic line with bottom of the 7.75 foot steel shell placed 6.0 feet beneath the surface, is nearly 1.5 cubic yards per lineal foot. Cost of excavation, mainly by steam shovel or scrapers, no rocks, easy soil, at 30 cents per lineal foot.

Cost of excavation, mainly by steam shovel or scrapers, no rocks, easy soil, at 30 cents per lineal foot	$0.45
For backfill, 1½ cubic yards, 75 per cent rehandled, at 20 cents for whole	.30
For trimming cut and backfill accurately by hand	.15
For pipe in dry ground, total	$0.90

Or, in round figures, say, $1.00 per lineal foot.

The Los Angeles work gave the following costs in excavation per lineal foot of siphon pipe, for larger pipe in much rougher ground of the canyon sides, by hand.

No Name Canyon, 9.25 foot diameter, excavation only, excluding backfill, per lineal foot	$1.23
Dead Man Canyon, 11 foot diameter, excavation only, excluding backfill, per lineal foot	1.02
Soledad Canyon, 10 and 11 foot diameter, excavation only, excluding backfill, per lineal foot	1.06
Placerita Canyon, 11 foot diameter, excavation only, excluding backfill, per lineal foot	1.96

The Los Angeles data do not dispute the sufficiency of the above figures of $1.00 per foot when the difference in conditions is considered.

For wet ground, or where concrete cradles are used, and the pipe bedded in four inches of concrete, the excavation adds for cradles only 0.10 cubic yards per lineal foot. The trimming of earth more precisely to cylinder adds, say, 10 cents per lineal foot, and cost of excavation in the more difficult wet material may be assumed at 70 cents per cubic yard, making cost of excavation and backfill in normal wet ground, including outbreak and irregularities, at, say, 2 cubic yards per lineal foot, $1.50, with extra for pumping in very wet ground, and extras for sheet piling and timber supports, extra concrete, etc., as required.

Concrete Covering and Mortar Lining

The method of applying the inside lining will probably be by grouting poured from the outside under a small head thru 2½-inch holes left in the shell and subsequently screw-plugged, against movable forms (as in New York), but with the addition of wire reinforcement to lessen any tendency to cracks.

The cost of the rich 1 to 2 mortar that will be used for this lining, including mixing and pouring, is estimated at $9.00 per cubic yard. This allowing per cubic yard of mortar:

3.1 barrels of cement at $2.00, equals	$6.20
0.87 cubic yard of sand at 50 cents, equals	.44
Mixing, hauling, pouring water and plant, equals	2.36
Total	$9.00

The quantity per lineal foot is, including the extra thickness for the large ring, .147 cubic yards.

0.147 cubic yards at $9.00, equals	$1.32
Add for setting up and taking down the collapsible forms, per lineal foot	.30
For wire reinforcement, per lineal foot	.20
Total per lineal foot	$1.82

(For confirmation, note that in Contract No. 68, New York Board of Water Supply, under certain adverse conditions, the contract price per lineal foot for a lining 33 per cent thicker on a pipe of 23 per cent greater circumference is $3.00 per lineal foot. The quantity of mortar per lineal foot for the San Francisco pipe is only about half as great and the forms may be much lighter and easier to handle.)

Total Cost Including Excavation, Back Fill and Cement Lining

Adding the above to the total cost of the steel pipe previously computed, we have for ordinary conditions and thickest pipe (¾ inch by 7.5 feet net diameter inside the lining) total cost per lineal foot, including mortar lining, excavation and backfill, $23.58 plus $1.00 plus $1.82 equals $26.40 per lineal foot, which equals $139,400 per mile, exclusive of contractor's profit, overhead charges and whatever loss of efficiency may result from lack of good, practical supervision or local conditions.

For the portion of the steel bedded in concrete in wet ground, the additional cost of the concrete is estimated as follows:

For 2 foot x 2 foot cradles, built of ordinary 1, 3, 6 concrete, each containing 2.3 cubic yards, or per lineal foot if 20 feet apart on centers, 0.12 cubic yards, at $8.00, including forms, $0.96, or including 38 feet of ¾-inch reinforcing rods in each cradle, per lineal foot	$1.00
The pipe bed, poured, of richer concrete, .16 cubic yard at $9.00	1.44
Cover of rich concrete, averaging 3 inches thick outside of steel shell, .09 cubic yard at $9.00	.81
Wire reinforcement for top half, 12 square feet	.05
Total cost of bedding and covering exterior of pipe with concrete in addition to the mortar lining	$3.30
The additional cost of excavation in wet ground has been previously computed to be	.50
Total additional cost per foot of conduit in wet ground over its cost in dry ground equals	$3.80

exclusivve of contractor's profit, overhead management charges, etc.

This does not include pumping in very wet ground nor extras for sheet piling, timber supports or extra concrete.

Variation of Cost of San Joaquin Aqueduct, With Thickness of Its Steel Shell

For estimating the cost of pipe at sides of the valley where the head is lower and the steel shell thinner.

The estimate already made of the cost of the pipe ¾-inch thick, weighing 860 pounds per foot, is used as the basis for the cost of pipes ¾-inch, ½-inch, and ¼-inch thick, with other thicknesses found by interpolation. The finished weight of steel pipe per foot for these thicknesses is computed as follows:

¾-inch, 860 pounds, butt joint, triple-riveting;
½-inch, 573 pounds, butt joint, triple-riveting;
¼-inch, 278 pounds, lap joint, double-riveting.

SUMMARY OF COST OF SAN JOAQUIN PIPE, WITH DIFFERENT THICKNESSES OF STEEL SHELL.

Net inside diameter=7 feet 6 inches.

Thickness of steel shell.	¾ inch, previously estimated.		½ inch.		¼ inch.	
Approximate weight of finished steel pipe, pounds per foot	860		573		278	
Maximum allowable head in feet on 7 ft. 9 in. diameter steel pipe to produce 15,000 lbs. per square inch net stress on joint of 88 per cent efficiency	492		328		140	
(75 per cent efficiency has been used for the ¼-inch pipe, which will have a lap joint instead of a butt joint.) Corrosion not considered.						
	Per 100 lbs. steel.	Per foot.	Per 100 lbs. steel.	Per foot.	Per 100 lbs. steel.	Per foot.
Steel, punched and delivered.	$2.00	$17.20	$2.00	$11.46	$2.00	$5.56
Wagon haul and handling	.10	.86	.12	.69	.14	.39
Placing	.15	1.29	.20	1.15	.30	.84
Riveting	.23	2.00	.28	1.60	.30	.84
Calking, cleaning and painting	.12	1.04	.18	1.04	.37	1.04
Net equipment after salvage	.12	1.00	.17	1.00	.35	1.00
Surveying and local supervision	.02	.19	.03	.19	.07	.19
Excavation and backfill		1.00		1.00		1.00
Concrete lining		1.82		1.82		1.82
Total cost of aqueduct in dry ground		$26.40		$19.95		$12.68

To the above must be added an allowance for contractor's profit, for contingencies, for the general overhead charges for engineering, business management, sanitation, etc., and also whatever allowance may be deemed proper for difference in efficiency and output of workmen under conditions prevailing in San Francisco, compared with those in Los Angeles.

APPENDIX 8—COST DATA FOR LARGE STEEL PIPE

Estimate of Cost of Steel Conduit for "Bay Head Crossing"

This Bay Head pipe is to carry water by gravity flow a distance of about nineteen miles, between the Mission Tunnel and the San Mateo Tunnel, and the maximum pressure upon it will be that due to delivering water from a full reservoir (El. 450) at San Antonio across the Bay into the Crystal Springs Reservoir at its future increased level of El. 325. The ordinary working pressure will be less. The maximum head thus imposed on the pipe at sea level will be about 375 feet. The head on sixteen miles of this pipe will average about 360 feet.

The following estimate is based mainly upon that already deduced for the pipe across the San Joaquin Valley. The Bay Head pipe will be less than half the length of the San Joaquin Valley pipe, of 1.0 foot smaller diameter, and the maximum head upon it will be about 115 feet less.

Both the San Joaquin and the Bay Head pipes are designed for a maximum stress upon the metal of 15,000 pounds per square inch, which is about one-half the elastic limit and one-quarter the required ultimate strength of the basic open-hearth "flange steel" proposed; all these requirements being the same as used on the recent large steel siphons for the New York Board of Water Supply.

For the same strength, a double-riveted lap joint of 75% efficiency would call for .087 inch thicker plate, and the finished pipe would weigh 70 pounds per foot more, than for a pipe with triple-riveted butt joint of 88% efficiency.

The finished pipe of ½-inch plate and with triple-riveted butt joint will weigh 490 pounds per foot, which is the weight used in the following estimate.

Cost of the steel, with rivet holes punched and drilled, and delivered near the site of the work will be substantially the same as for the San Joaquin Valley pipe, $2.00 per 100 pounds.

Wagon Haul, Loading and Unloading

A figure of 10 cents per 100 pounds, or 86 cents per foot, was adopted for the San Joaquin Valley pipe, weighing 860 pounds per lineal foot. The Bay Head pipe will weigh 370 pounds less per foot and should cost slightly more per pound to handle, since there will be more pieces in a given weight. The wagon hauls from the Bay shore, though not as level, would be about as short as in the San Joaquin Valley, averaging four miles from Cooley's landing on the west shore and five miles from Plummer landing on the east shore. Existing roads can be used to a great extent. The Los Angeles hauls in the foothills cost about 9 cents per 100 pounds for pipe about as heavy per foot as the Bay Head pipe, but of ten or eleven feet diameter, instead of seven feet, and hence more difficult to handle. Twelve cents per 100 pounds is adopted for wagon haul of all but the submerged portion. For the majority of the Bay Head pipe, weighing 490 pounds per foot, the corresponding cost per foot is 59 cents.

Placing

Except over the salt marsh, natural conditions here are nearly as favorable as for the long, continuous level stretch of San Joaquin pipe, for which a figure of 15 cents per 100 pounds or $1.29 per foot, was adopted. The lighter weight of the Bay Head pipe would increase the cost per foot, but would tend to increase its cost per pound. It would be joined into three 10-foot lengths in the field shop, and a fill over the soft marsh some fifty feet or more in width would have been prepared by dredges, much as reclamation dikes are built, a year in advance, on which the hauling and placing would be done for that portion. Estimate 20 cents per 100 pounds for placing, equivalent to 98 cents, or say, $1.00 per foot.

Bending and Riveting

The San Joaquin estimate was based on work mostly done in a field shop at a total cost, including plant, power, maintenance and moving, of $2.00 per foot, equivalent to 12 cents per 1¼-inch rivet. A unit price of 9 cents per rivet applied to the seventeen ⅞-inch rivets per foot of the Bay Head pipe, including round-about seams, equals about $1.50 per foot, or about 31 cents per 100 pounds.

Calking, Removing Rust, and Painting, etc.

Calking the San Joaquin Valley pipe was estimated at 4 cents per 100 pounds, or 35 cents per foot, and painting at 8 cents per 100 pounds, or 69 cents per foot, making a total of 12 cents per 100 pounds, or $1.04 per foot.

For the somewhat smaller Bay Head pipe, use *90 cents* per foot, or 18 cents per 100 pounds for calking, cleaning and painting.

Construction Plant and Temporary Supports

The same plant can be used for the Bay Head as for the San Joaquin pipe. Allow *$1.00* per foot for use and depreciation.

Local Engineering Costs

Use the San Joaquin figure, *19 cents* per foot.

Summary of Cost of Bay Head Steel Pipe, for Steel Only

(Exclusive of submerged portion).

Erected complete in place, exclusive of excavation, backfilling, concrete lining, concrete bed, special structures, etc.

For pipe ½ inch thick, 6 feet 9 inches inside diameter, weighing 490 pounds per foot, having only one longitudinal seam.	Cost per lineal foot.	Cost per 100 pounds.
Steel (via Panama Canal), punched, shaped and delivered near aqueduct	$9.80	$2.00
Hauling by wagon, including loading and unloading	.59	.12
Placing	1.00	.20
Riveting	1.50	.31
Calking, cleaning inside and out, and painting.....	.90	.18
Equipment, net, after salvage..................	1.00	.20
Engineering (surveying and local supervision).....	.19	.04
For steel work only, at "Bay Head Crossing".....	$14.98	$3.05
The corresponding totals for the San Joaquin steel pipe, weighing 860 pounds per foot, are.......	23.58	2.74

Note that the above estimate gives the minimum or base cost, under exceptionally favorable conditions, and does not include contractors' profit, overhead costs of management, etc., nor does it allow for inefficient management or bad labor conditions.

Excavation and Backfill

In the case of the San Joaquin Valley pipe, the estimated average yardage in dry ground was 1½ cubic yards per foot, excavation and backfill to cost $1.00 per foot. Under similar conditions the Bay Head pipe would require about 1.20 cubic yards per foot of very easy digging. Use 80 cents per foot in dry ground and $1.25 per foot in wet ground. For the four or five miles over tidal salt-marsh land, as already suggested, it is proposed to lay a foundation for durability and convenient access by first filling a strip 50 to 100 feet wide up to a height of five feet above mean high water, on top of which the pipe will be placed, on a thin bed of concrete, and the whole pipe subsequently covered with earth.

Mortar Lining

Estimating the lining of the Bay Head pipe on the same basis used for the San Joaquin pipe, but allowing for the difference in circumference, the thickness of mortar and method of application being the same we have:

Mortar lining, $1.32 x 6 ft. 9 in. dia.÷7 ft. 9 in. dia.=	$1.15 per lin. foot.
Forms	.30
Reinforcement (steel wire netting), say..............	.19
Total per lineal foot of pipe..................	$1.64

SUMMARY OF COST OF BAY HEAD STEEL PIPE ½ INCH THICK, LINED WITH CONCRETE.

Net inside diameter=6 feet 6 inches.	In dry ground.	In wet ground.
Cost of steel pipe erected complete in place	$14.98	$14.98
Excavation and backfill	.80	1.25
Concrete lining	1.64	1.64
Bedding and concrete covering (over marsh)	—	2.95
Total, not including possible additional cost in extra wet ground for pumping, sheet piling, filling, etc.	$17.42	$20.82
Equivalent cost per mile	$92,000	$110,000

Variation of Cost of Bay Head Aqueduct, With Thickness of Its Steel Shell

Starting with the cost just estimated for the pipe ½ inch thick, containing 490 pounds of steel per foot, an estimate is made of the cost of pipes ½ inch, ⅜ inch and ¼ inch thick and other thicknesses found by interpolation.

SUMMARY OF COST OF BAY HEAD PIPE WITH DIFFERENT THICKNESSES OF STEEL SHELL.

Net inside diameter=6 feet 6 inches.

Thickness of steel shell.	½ inch, already estimated.		⅜ inch.		¼ inch.	
Approximate weight of finished steel pipe, pounds per foot	490 Triple-riveted joint.		355 Double-riveted joint.		235 Double-riveted joint.	
Maximum allowable head in feet to produce 15,000 lbs. per square inch net stress. Butt joint has 88 per cent efficiency, and lap joint 75 per cent	376		240		160	
	Per 100 lbs. steel.	Per foot.	Per 100 lbs. steel.	Per foot.	Per 100 lbs. steel.	Per foot.
Steel, punched, drilled and delivered	$2.00	$9.80	$2.00	$7.10	$2.00	$4.70
Wagon haul and handling	.12	.59	.13	.46	.15	.35
Placing	.20	1.00	.24	.85	.30	.70
Riveting	.31	1.50	.30	1.05	.35	.82
Calking, cleaning and painting	.18	.90	.25	.90	.38	.90
Net equipment after salvage	.20	1.00	.28	1.00	.42	1.00
Surveying and local supervision	.04	.19	.05	.19	.08	.19
Excavation and backfill		.80		.80		.80
Concrete lining		1.64		1.64		1.64
Total cost of aqueduct in dry ground, per lineal foot		$17.42		$13.99		$11.10

To the above must be added an allowance for contractor's profit, for contingencies, for the general overhead charges for engineering, business management, sanitation, etc., and also whatever allowance may be deemed proper for difference in efficiency and output of workmen under conditions prevailing in San Francisco, compared with those in Los Angeles.

Data For Smaller Distribution Mains

Portland Pipes Cost Data

On the recent 24-mile line of Lock-bar pipe for Portland, Oregon, of which about 40% was 52 inches and 60% 44 inches diameter, thickness varying from ¼ to 7/16 inch; the contract included furnishing and laying the pipe, so no such itemized costs are available as for Los Angeles, nor are the sizes so great as required for the main Hetch Hetchy lines. They are comparable with pipes that might be used for delivery from the end of the tunnel to communities about the bay, except that these Portland pipes were generally in a much rougher and more inaccessible country. Presumably a roadway already existed along the pipe line, built when the previous pipe was laid.

The contract prices on the Portland pipe were:

52 inches diameter, 7/16 inch thick, $13.00 per lineal foot, laid.
52 " " ⅜ " " 11.00 " " "
52 " " 5/16 " " 11.00 " " "
52 " " ¼ " " 8.90 " " "
44 " " ¼ " " 6.50 " " "

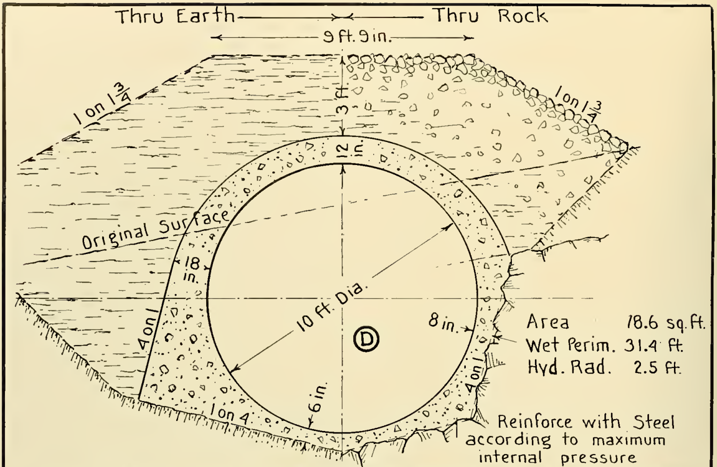
On our heavier pipes in an ideally level country, free of rocks, the cost would be relatively much less.

The following notes by the Assistant Engineer, Mr. Morrow, are of special interest in illustrating the rapid work and low costs obtainable with modern appliances on a large continuous job, and tend to confirm the sufficiency of the estimates already adopted:

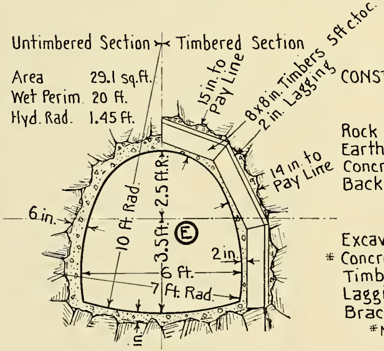
Diameter Thickness	52 inches. 5/16 inch.	44 inches. ¼ inch.	52 inches. 5/16 inch.	44 inches ¼ inch.
			Cost per lineal foot.	
Laying—One crew of seven men, payroll $24.00, with pipe-laying machine (traveling derrick with gasoline engine)	—	—	$ .0889	$ .0533
Amount laid per 9-hour day on country road; pipe handled in 30-foot lengths:				
Ordinary	270 feet.	450 feet.		
Maximum	330 "	930 "		
Laying up laps—One crew of two men, payroll $5.00, averaged per day	7 sections.	15 sections.	.0286	.0133
Riveting—One crew of three men, payroll $12.00, averaged per day, only the round seams, one each 30 feet	5 seams.	6 seams.	.0800	.0669
Calking—One calker, payroll $5.40, averaged per day	5 seams.	6 seams.	.0720	.0600
Painting—One man, payroll $3.00, averaged in length of pipe per day	100 feet.	100 feet.	.0300	.0300

Our San Joaquin pipe, 93 inches in diameter, being about double the above average diameter, presents only double the surface to be painted and double the length for each field seam to be riveted, with fewer but larger rivets.

The power of the gas engine on the laying machine would take care of the large difference in weight at less cost per pound.



CUT AND COVER BY-PASS FOR CRYS. SPRGS. RES.



CONSTRUCTION QUANTITIES per lineal foot

Section Ⓓ

	Thru Earth	Thru Rock
Rock Excavation		2.20 cu.yd.
Earth "	6.85 cu.yd.	1.74 " "
Concrete	1.83 " "	1.27 " "
Back Fill	6.02 " "	3.31 " "

Section Ⓔ

	Untimbered	Timbered
Excavation	1.44 cu.yd.	1.88 cu.yd.
* Concrete	0.37 " "	0.75 " "
Timbers		18. B.M.
Lagging		35 "
Bracing etc.		8 "

*Main Timbers -assumed left standing

TYPICAL TUNNEL SECTION
THRU SAN BRUNO MTS.
FOR "ALTERNATIVE PIPE LINE"
Minimum Section - Made wide for cars at bottom

CONDUIT SECTIONS
DISTRIBUTION AQUEDUCT

For Report of John R. Freeman
Aug. 1, 1912

Appendix No. 9

PRELIMINARY ESTIMATE OF COST OF THE HETCH HETCHY PROJECT

By Horace Ropes, C. E., in Consultation with
John R. Freeman, C. E.

Data on Which Estimate is Based

The following estimate of the cost of the several tunnels, pipe lines, cut and cover aqueduct, reservoirs and appurtenant structures required to deliver water from the Hetch Hetchy Reservoir to a receiving and distributing reservoir in the San Miguel hills at a point in San Francisco three miles southwest from the City Hall, has been based as far as possible on Mr. Freeman's reasoning and data given on pages 223 to 237 of his report. The intention has been to have the costs accord with those recently obtained for similar work on the new Los Angeles Aqueduct.

This estimate applies to an aqueduct located and designed as shown on the maps, profiles and other drawings presented by Mr. Freeman. The excellent topographical maps of the U. S. Geological Survey have been mainly relied on for the selection of the general route of the aqueduct, but for all important features such as power drops, river crossings, deep shaft locations, dam and reservoir sites, etc., lines of spirit levels have been run to check the elevations at critical points or special surveys have been made to obtain more accurate and extended information than is given on the maps mentioned.

After the first field trial line for the aqueduct had been selected from many "paper locations" and drawn on the map, a field inspection was made for substantially the full length of the line, to note character of material to be excavated, accessibility and other conditions affecting the cost of the work. Expert advice relative to the geologic structure for the deep underground tunnels was obtained and used to advantage in making changes of location to avoid difficult and expensive work, also to determine with a fair degree of certainty the character of the rock and the distance to be tunneled through the various geologic formations to be encountered.

Typical Sections for Tunnels

Typical sections were designed for the three principal sizes of tunnel proposed for the main aqueduct, showing the ordinary requirements for concrete lining in sound rock, and in cases where timbering must be used. These principal designs are shown on page 120, and supplementary designs on the opposite page.

Where external pressures from great weight of loose material, or from an excessive head of ground water occur, the concrete lining must, at the discretion of the engineer in charge, be made thick enough to resist them, making the cost of the lining for different stretches of tunnel variable according to the conditions which ultimately develop. The sections on page 120 show the difference in thickness of concrete lining as estimated for minimum and maximum lining in tunnels of 10 feet net diameter, also the maximum thickness considered for tunnels of 12.8 feet net diameter.

The quantities of excavation, concrete and timber for the above typical cases are noted on the drawing. In cases where the use of less than the maximum thickness appears to be safely permissible, the excavation and concrete quantities for estimating cost have been reduced in accordance with careful judgment of probable conditions, but in no case to less than six inches average thickness of lining. In exceptional cases such as the inclined tunnels at the power drops, or tunnels through loose water bearing gravels, where the internal or the external pressures are very great, a much thicker lining has been provided for in the estimate of cost.

The Method Followed in Making These Estimates

First, an estimate is made based on the cost data derived from the records of actual work done on the Los Angeles Aqueduct. That work was built by a force employed directly by the city, and the monthly cost statements having been made up from the force account records of labor and materials relate mainly to the field work or to what may be called the direct cost of construction; the overhead charges, such as administration, general engineering, cost of heavy plant, etc., having been quite generally disregarded in the force accounts and carried as separate items, without attempting to apportion their cost to the various classes of work performed while the work was in progress, or prior to sale of the salvage.

The adoption of unit costs comparable with those obtained for similar work at Los Angeles gives then mainly the construction or field cost of the work and, to obtain the total cost of the project, it will be necessary later on to add the probable expense for items now temporarily omitted.

The unit costs of construction per foot in length as used herein are intended to include all items of expense EXCEPT the proportionate cost of heavy plant (compressors, hoists, drills, pumps, crushers, concrete mixers, miscellaneous machinery, rails, rolling stock, etc.) after the salvage has been deducted; the unit costs also temporarily exclude the following items, which are added later in the summary for the particular divisions, viz: The cost of building roads and trails; the cost of contractor's bond and liability insurance, transportation of laborers and contractor's profit; the greneral expenses at city headquarters—administration, legal services, general engineering design, etc.; surveys and bench levels, and interest during construction; also the cost of acquiring lands and easements for right of way and construction purposes.

Special items which are known to have been considered and included in the unit costs obtained at Los Angeles from month to month are local engineering, field superintendence and other local overhead charges; cost of electric power, buildings, minor equipment and miscellaneous losses; also first cost, with maintenance and operation of pipe lines, local telephones and maintenance of roads and trails.

The above separation of charges is adhered to mainly for the purpose of having the prices here adopted, comparable with the actual costs of similar work, as given in the monthly reports of the Los Angeles Aqueduct. It is quite logical, however, to defer the omitted charges until the end because—

(1) The cost of heavy plant, and the building of roads and trails, is materially affected by the difference in accessibility to the work and on different divisions is correspondingly less or greater than an average allowance, varying as the facilities for transportation are good or bad.

(2) It is desired to compare the cost of the work as done by the Los Angeles method of day labor, with the cost of same when done by contract, with the customary 10 to 15 per cent added for contractor's profit. As the contractor is not entitled to profit on general administration, engineering, etc., and is entitled to interest on his working capital only, which latter would be a small fraction of the total cost of the work, it has been necessary to keep the charges for administration, engineering and interest during construction, distinct from the charges which directly concern the contractor, and not to include them in the total until after the contractor's profit has been figured.

There is a slight complication caused by the item of local engineering on which the contractor is not entitled to profit, having been included in the first group of construction costs, but this is probably fairly well balanced by the omission of interest on the contractor's working capital.

Assumed Base of Wages

The prices used are based on a wage of $2.25 per day of eight hours for unskilled labor, which is a higher rate than the average now paid by contractors doing work of this same general character outside of the city, and is the same as the average price paid by the city of Los Angeles for unskilled labor on its new aqueduct.

The Los Angeles work has been done under exceptionally good management. With ordinary management of day labor work under city control, and the San Francisco scale of wages the cost of the work would be materially increased.

In the final rounding up of the estimate it is intended that the allowances for items previously omitted shall be conservatively liberal, making the estimated total assuredly ample for the completion of the works after providing for all contingencies except an abnormal rate of wages and inefficient management. Since abnormal wages and moderately inefficient management might easily add from five to ten million dollars to the cost of the Hetch Hetchy Aqueduct, all of which would ultimately have to be met in the water rates, it is assumed that great care will be given to starting these matters right.

Divisions of the Aqueduct

For convenience in considering the different possibilities in future plans for construction, the work has been divided into fifteen divisions, listed below in their consecutive order from San Francisco to Cherry Reservoir, but this order is not necessarily the order of their construction. Divisions 13, 11 and 12 will be the first, while 3 and 10 will probably be the last to be constructed.

Division 1. *San Miguel-Millbrae*—Comprising a main aqueduct from the proposed San Miguel distributing reservoir to the vicinity of Millbrae, where a branch line will connect Lake San Andreas with the main line. Branch lines can also be run to the existing distributing reservoirs at University Mound and College Hill. Length of pressure tunnel aqueduct 9.70 miles, or for alternative pipe line 9.25 miles.

Division 2. *Millbrae-San Mateo*—A section of the main aqueduct extending from the San Andreas Lake junction to a connection with the Crystal Springs Lake at the San Mateo dam. Length for pressure tunnel aqueduct 5.40 miles, or for alternative pipe line 6.50 miles.

Division 3. *Crystal Springs Lake*—The proposed by-pass section of main aqueduct, mostly masonry conduit in open trench, skirting the east shore of Crystal Springs Lake from

San Mateo dam to a connection with the tunnel, one and a half miles south of the south end of the lake. Length 6.20 miles.

Division 4. *Crystal-Irvington*—Extending from the south end of the "cut and cover" aqueduct near Crystal Springs Lake to the Irvington Gate House at the east end of the Dumbarton pipe siphon, and at the junction for possible future branches to Lake Chabot and San Jose. Length 22.35 miles.

Division 5. *Irvington-Calaveras*—Extending from Irvington Gate House to east bluff of Alameda Creek Valley, where a short branch will bring in the water from Calaveras reservoir in case it is built and available. Length 4.55 miles.

Division 6. *Calaveras-Antonio*—Extending from Calaveras junction to the junction point of short connection with the proposed San Antonio reservoir, provided said reservoir is to be built at an early date. Length 2.15 miles.

Division 7. *Antonio-Valle*—Continuation of the main aqueduct from the San Antonio reservoir connection to the shaft site in the canyon of Arroyo del Valle. This shaft can be made to serve as an intake for the waters from the proposed Arroyo del Valle reservoir, if it is ever built. Length 6.85 miles.

Division 8. *Valle-Moccasin*—Extending from Arroyo del Valle to Moccasin Creek. Length 80.60 miles of main aqueduct, and possibly 6 or 7 miles additional of branch line.

Division 9. *Moccasin-Early Intake*—The extension of the main aqueduct from Moccasin Creek to the intake from the Tuolumne River, at a point one and one-half miles upstream from Cherry Creek. Length 19.50 miles.

Division 10. *Canyon Division*—Extending from the power house sit just below the Early Intake to the Gate House at Hetch Hetchy dam. Length 12.10 miles.

Division 11. *Hetch Hetchy*—Includes the Hetch Hetchy dam and appurtenances, and the Hetch Hetchy reservoir.

Division 12. *Eleanor-Cherry*—Includes the 8-foot tunnel, and the reservoirs at Lake Eleanor and Cherry Creek necessary to divert the water from those sources to the Hetch Hetchy Reservoir. Length 6.8 miles.

Division 13. *Construction Roads*—Main line from Rosasco on the Sierra Railroad to Hetch Hetchy dam, also short branch roads where necessary to sundry shaft sites, etc. Length about 60 miles.

Division 14. *Scenic Roads*—Comprises the proposed carriage road along the Hetch Hetch reservoir, and the road to Tiltill Valley. Length optional, say 10 miles of excellent road 15 feet wide, and 10 miles of cheaper road for completing the line.

Division 15. *Irvington-Chabot*—The branch line from Irvington Gate House to an outlet into Lake Chabot. Length 15.55 miles.

Division 16. *Popenaut Dam and Reservoir*—These are auxilliary structures adding to the efficiency and scenic value of the project, but would probably be deferred.

Cost of Portland Cement

As the aqueduct is extended farther and farther from San Francisco, particularly after it reaches the mountain region east of San Joaquin Valley, transportation charges on material entering into construction become an important element in the cost of the work.

Special notice of this must be taken in determining the cost of cement, a very weighty substance, of which large quantities will be required for lining of the tunnels and for miscellaneous masonry structures. With a first cost of little more than one-third of a cent per pound for cement at the mill, the charges for handling and transportation quickly reach an important proportion of the final cost when the haul from the mill to the work exceeds a very moderate distance.

The cost of cement manufactured in California and delivered at the different working points along the line has been determined for the several divisions, as follows:

It is stated on reliable authority that:

The Harbor Board has a contract for 70,000 barrels cement delivered f. o. b. San Francisco, at $1.64 per barrel, which with freight deducted makes price f. o. b. at mill (cost of sacks additional) . . . . $1.50 per bbl.

The State Engineer's Department pays f. o. b. at the mill (cost of sacks additional) . . . . $1.45 per bbl.

One of the railroad systems entering San Francisco pays f. o. b. at mill for purchases, probably in smaller lots (cost of sacks additional) . . . . $1.60 per bbl.

On a large dam now being built in the Sierras, the builders have a contract for a large lot of cement which costs, delivered at the dam site, $3.60 per barrel, or deducting the wagon and railroad freight gives price at mill (cost of sacks additional) . . . . $1.30 per bbl.

The actual cost to manufacture is probably well inside the above prices, and the price at which the mill can afford to sell depends largely on size of contract, time of delivery and duration of contract. In all these respects this aqueduct work is entitled to the lowest possible prices—and still lower prices could doubtless be obtained by special provisions for shipment in bulk, and by provision for large storage at dam site and acceptance of delivery in the dull season.

Cement is usually shipped in sacks, four to the barrel. An extra charge of 10 cents is made for each sack, but this is refunded for sacks returned in good order. Usually about one-quarter of the sacks are lost or damaged, thus increasing the final cost of cement by about 10 cents per barrel, which should be added to the above prices.

It is believed that for the large quantity of cement to be used on the Hetch Hetchy dam and aqueduct even more favorable rates than those above quoted can be obtained, possibly as low as $1.25 per barrel, exclusive of sacks, but to be safe the base price for the Hetch Hetchy project is assumed as f. o. b. at the mill, not including cost of sacks............$1.45 per bbl.

Transportation Costs for Cement

Some large cement works are located in the vicinity of Napa and Suisun, which may be assumed to be the points of origin for all shipments. The railroad hauls and rates to Tracy and Oakdale on the Southern Pacific Railway, and to Rosasco on the Sierra Railroad, give a scale by which to estimate the freight on cement delivered to other convenient points.

Suisun to Tracy, 68 miles, rate 22 cents per barrel.
Suisun to Oakdale, 120 miles, rate 33 cents per barrel.
Suisun to Chinese, 155 miles, rate $1.09 per barrel.

The rate per ton mile for cement appears to be—

On Southern Pacific Railroad, about 1½ to 1¾ cents, according to distance.

On Sierra Railroad, about 8 to 9 cents, according to distance.

Wagon haul in the mountains commands a high rate. Between Chinese and Groveland, distance 16 miles, with generally good country road and moderate grades, except a long descending grade between Chinese Camp and Woods Creek, and Priests Hill, about two miles long, where the adverse grade is 18 per cent or more, the wagon haul rate is 60 cents per 100 pounds, or $12.00 per net ton, equivalent to 75 cents per ton mile. The new highway now under construction for avoiding Priests Hill, and which reduces the maximum gradient to 6 per cent, is expected to lessen this cost by 30 cents per 100 pounds.

On the Los Angeles work the road haul was all done with horses, at an actual cost of 12½ cents per ton mile for much of it.

In this estimate, however, it is presumed that a new road with much lighter gradients will be completed in advance of other heavy construction, so that the wagon haul rate should not exceed 20 cents per ton mile, or if a temporary railroad or motor trucks were to be used on a roadbed thoroughly well kept up the rate could be reduced to 7 cents per ton mile, or less.

It has been assumed for the mountain work that cement would be delivered at Rosasco by rail at $2.05 per barrel, and thence by motor truck or by rail over a newly-constructed road at an additional cost of 7 cents per ton mile. An additional charge of 20 cents per barrel has been allowed on the mountain work for extra handling and waste, and other uncertainties.

The prices used range from $1.70 per barrel near San Francisco, to $3.00 per barrel at Hetch Hetchy dam, this price covering the haul, but no part of the cost of the new road or the new railroad.

Unit Costs for Concrete

It is designed to make the tunnel lining as thin as practicable; and in sound rock, and where no great external pressures from loose materials or high heads of ground water are to be sustained, the specified thickness is 6 inches, though less will be permitted over minor projections. For strength and imperviousness this concrete should be a fairly rich mixture, and it has been assumed as one part by volume of cement to two and a half parts sand and five parts gravel or crushed stone. There will of course be places where a mixture even richer in cement will be required to give the requisite strength or water-tightness; and then again at other points the density of the rock may be such that the lining is only needed to smooth the rough interior and give the tunnel its maximum capacity, and a poorer mixture will suffice. In the latter case the proportion of cement in the aggregate may safely be made smaller. It is fair to assume that these variations from the standard adopted will practically balance each other in cost.

For tunnels of the same finished diameter, those which must be timbered have to be excavated to larger size in order to admit the main timbers and leave a clearance of two or more inches to the face of the lining in places where, as usually is the case, it will be unsafe to remove the timber prior to placing the lining.

Because of their larger section, timbered tunnels require more concrete per lineal foot than untimbered sections, and as some of the elements of cost are practically constant per lineal foot for both sections of tunnel, when these elements are reduced to a cubic yard basis it results in a difference in the cost of concrete at different places in the same tunnel.

The items which remain constant per lineal foot of tunnel are making of forms, taking down and resetting the forms, and plastering the surface of the concrete.

On the assumption that 500 lineal feet of moveable forms will serve for each mile of tunnel, we have:

	6 feet, diameter tunnel.	10 feet, diameter tunnel.	12.8 feet, diameter tunnel.
	Per foot.	Per foot.	Per foot.
Allowance for 500 lineal feet forms, per mile	$ .19	$ .34	$ .45
Note: Estimated cost of making forms— 6 feet diameter, $2.00 per foot. 10 " " 3.60 " 12.8 " " 4.80 "			
Taking down and resetting forms	.15	.30	.40
Plastering inner surface	.35	.60	.80
Total	$ .69	$1.24	$1.65

Converting the above lineal foot costs to the cubic yard basis, and assuming that 25 per cent of the length will require the heavy section of lining—

In 6- ft. timbered tunnel,	$ .75	c. y. concrete at	$ .69	per ft.,	$ .92	per c. y.
" 6- ft. untimbered "	37	" "	.69	"	1.90	"
" 10- ft. timbered "	1.43	" "	1.24	"	.87	"
" 10- ft. untimbered "	.70	" "	1.24	"	1.77	"
" 12.8-ft. timbered "	1.82	" "	1.65	"	.91	"
" 12.8-ft. untimbered "	1.00	" "	1.65	"	1.65	"

COST OF ONE CUBIC YARD OF CONCRETE IN TUNNEL

Proportions of aggregate by volume: 1 cement, 2½ sand, 5 stone
One barrel cement equals 3.8 cubic feet.

	6 feet, diameter tunnel.	10 feet, diameter tunnel.	12.8 feet, diameter tunnel.
Cement, 1.3 barrels at $1.70	$2.21	$2.21	$2.21
Stone, .92 cubic yard at $1.00	.92	.92	.92
Sand, .46 cubic yard at 50 cents	.23	.23	.23
Mixing and deliverying to mouth of tunnel or shaft	.80	.80	.80
Extra work cleaning walls of tunnel and placing concrete	.55	.55	.55
Cost of forms, setting forms, and plastering as estimated above for timbered tunnels	.92	.87	.91
Total cost per cubic yard for TIMBERED TUNNEL	**$5.63**	**$5.58**	**$5.62**
For untimbered tunnels, add for greater proportionate cast of lineal foot items due to the smaller yardage per lineal foot	.98	.90	.74
Total cost per cubic yard for UNTIMBERED TUNNEL (With cement at $1.70 per barrel, delivered at site of work.)	**$6.61**	**$6.48**	**$6.36**

Apparently concrete in timbered tunnel will cost from 75 cents to $1.00 less per cubic yard than in untimbered tunnel, but taking into account the expense of removing lagging and some timbers will bring the cost to practically the same figures as for untimbered tunnels, and the latter have been used in the estimate for both classes of tunnel.

For each increase of 10 cents per barrel in the price of cement, add 13 cents to the above costs per cubic yard.

The cost of sand and stone will also be variable in different localities, and where of sufficient importance this has been taken into account in special cases. The prices for stone and sand as used in the preceding table are assumed as sufficiently near the average cost to serve in this computation for comparison of cost of concrete in timbered and untimbered tunnels. Indications are favorable for a cheap supply of good sand at many of the shaft sites, but where it is not readily obtainable within a short distance it can be supplied artificially for not to exceed $1.00 per cubic yard by pulverizing tunnel debris.

Unit Costs for Tunnels

Three sizes of tunnel appear in the following estimates, namely, 6 feet, 10 feet and 12.8 feet diameter inside of the lining. The costs per lineal foot will be widely variable, depending on the size and length of the tunnel, the character of the materials to be driven through, the relative cost per cubic yard for concrete lining, and whether or not the tunnel requires timbering.

The probable costs per lineal foot of tunnels driven under widely variant conditions as to locality; character of rock formation, whether hard or soft, sound or fractured, and wet or dry, have been based first on the knowledge derived from personal experience as to the results from actual work done under the writer's supervision, and then those results, suitably modified in accordance with careful judgment of local conditions as learned from field observations over substantially the full length of the line, made in company with Professor Branner, the consulting geologist, have been compared with the Los Angeles costs tabulated on pages — and —, and with the costs of other tunnels, in the mountain regions of the West, of which authentic information is at hand.

The different geological formations have been individually considered, a special estimate of tunnel cost per linear foot having been made for each of them.

Two examples of the method followed are given on the following page.

Redwood Tunnel.—(Mile 25.5 to 28.5—3 miles) 15,800 linear feet, 10-foot diameter, tunnel worked from two portals and two shafts. No drift need exceed one-half mile in length. Formation is hard rock of the Franciscan series, mainly San Bruno sandstone, but also some serpentine—probably much shattered in places because of proximity to San Andreas fault line—say 60 per cent will require timbering. Little water and no serious difficulties to be expected. Use light section of concrete lining.

REDWOOD TUNNEL.

TIMBERED TUNNEL.	Per lineal foot.
*Timbering and dry packing	$ 6.00
†Excavation, 4.5 cubic yards at $4.25	19.13
‡Concrete, 1.5 cubic yards at $6.60	9.90
§Miscellaneous	3.50
	$38.53
UNTIMBERED TUNNEL.	
†Excavation, 3.8 cubic yards at $5.00	$19.00
‡Concrete, .8 cubic yard at $6.60	5.28
§Miscellaneous	3.00
	$27.28
$38.53 x 60 per cent of entire length timbered	$23.12
27.28 x 40 per cent of entire length untimbered	10.91
	$34.03
Add for some long haul and shaft hoisting	.40
	$34.43
SAY $34.45 PER LINEAL FOOT.	

Note: Making due allowance for differences in area and yardage, the cost of $34.03 compares favorably with the average cost of Los Angeles tunnels 3, 8, 28 and 29, which give $33.60 per foot as adjusted cost of tunnels 80 square feet sectional area, which is the area of the tunnel under discussion.

*Timber at $50 per 1,000 feet, and dry packing $1.00 per foot, comparable with Los Angeles tunnels numbers 3 and 8 (see page 225). Average cost of timbering and packing for tunnel of 58 square feet area was $5.00, which increased proportionately for difference in circumference, requires the addition of 17 per cent of $5.00, or 85 cents, making a total of $5.85 to apply to this tunnel of 80 square feet area, for which $600 per foot has been allowed in this estimate.

†Comparable with Los Angeles tunnels numbers 8 and 28, which show an average cost of $4.50 per cubic yard for a 25 per cent smaller section than now being considered. The cost of excavation in the timbered portion of any given formation is usually less than in the untimbered, because in the latter the rock is harder and less broken, therefore requiring more drilling and powder. Say $4.25 per cubic yard for timbered tunnel, and $5.00 for untimbered.

‡Concrete cost is estimated as previously described, but based on cement at $1.80 per barrel.

§Miscellaneous includes local superintendence and engineering, minor equipment and expense of ventilation, pumping at shafts and other incidentals which are assumed to be somewhat greater for timbered than for untimbered tunnels.

Tesla Tunnel.—About two miles of 12.8-foot diameter tunnel through Chico formation, consisting of interbedded medium hard and soft sandstones and clays, worked from two shafts 300 and 500 feet deep, with extreme haul of one mile, probably considerable water, 80 per cent timbered; use medium heavy concrete lining.

TESLA TUNNEL.

TIMBERED TUNNEL.	Per foot.
Timbering and packing	$ 7.50
*Excavation, 6.8 cubic yards at $3.30	22.44
†Concrete, 1.9 cubic yards at $7.30	13.87
‡Miscellaneous	4.00
	$47.81
UNTIMBERED TUNNEL.	
*Excavation, 5.8 cubic yards at $4.00	$23.20
†Concrete, 1 cubic yard at $7.30	7.30
‡Miscellaneous	3.70
	$34.20
$47.81 x 80 per cent of entire length timbered	$38.25
34.20 x 20 per cent of entire length untimbered	6.84
	$45.09
Because of long haul to and high lift from deep shafts, add	2.82
	$47.91
SAY $48.00 PER LINEAL FOOT.	

Note: Making due allowance for differences in area and yardage, $45.09 per cubic yard compares favorably with tunnel number 73 of the Los Angeles aqueduct, which cost $48.29 per lineal foot for a tunnel 2½ per cent larger sectional area, driven through hard slate, described as "broken, but undisturbed in places," and with 86 per cent of its length timbered. This cost of $48.29, when modified to apply to the 2½ per cent smaller area, and 6 per cent shorter proportion of timbering for the Valle tunnel, becomes $47.06 per lineal foot. This is $1.97 per foot more than the cost price (exclusive of long haul and shaft work) estimated for the Valle tunnel, but the difference can be accounted for by the harder rock and the larger allowance for timbering.

In tunnel 73, timbering cost $7.31 per lineal foot, or $1.31 more than estimated for the Valle tunnel. Deduct $1.31 from $1.97 leaves a balance of cost due to the harder rock of 66 cents per lineal foot to be apportioned to 6.5 cubic yards of average excavation, or 10 cents per cubic yard, which is a reasonable difference.

*The excavation price as assumed is about 25 cents per cubic yard higher than the average cost for 7,600 feet of sandstone, slate and schist in Los Angeles tunnels 8, 9, 10 and 14.

†The concrete price is based on cement at $2.30 per barrel, and after excluding the allowance for plastering, is substantially the same as the actual cost of lining in tunnel 73.

‡Miscellaneous includes local superintendence and engineering, minor equipment and expense of ventilation, pumping at shafts and other incidentals which are assumed to be somewhat greater for timbered than for untimbered tunnels.

Similar consideration and care has been given to establishing the unit prices for each of the remaining tunnels to be estimated.

Tabulation of Unit Prices for Tunnel Work

The following table shows in parallel columns for convenient comparison the unit prices adopted for each tunnel. These prices are designed to cover all the working costs for labor and materials, including local overhead charges for engineering, superintendence, camps, telephone and power lines, pipe lines, power and minor equipment.

The prices DO NOT include any charges for administration and general engineering at city headquarters, for purchase and installation of heavy plant, for contractors' profits, or for interest on money expended during the construction period.

Allowance will be made later on for the items omitted, also to provide for higher rates of wages than those based on $2.25 per eight-hour day for common labor.

As the prices now stand they are comparable with the costs obtained on actual work done within the last two years on the Los Angeles Aqueduct.

In comparing the figures in this table with those of the Los Angeles Aqueduct, tabulated on pages 224 and 225, due regard must be given not only to the similarity of the materials in the sections compared, but also to their relative areas and lengths of timbered and untimbered tunnel in each case.

Other things being equal, the cost per cubic yard of excavation decreases with an increasing area of tunnel section, while the cost of timbering, lining, cleaning and plastering increase somewhat in proportion to any increased length of the perimeter involved.

Since in any given formation the untimbered portions will usually occur in the hard, firm ground, and the timbered in the loose, fractured rock, requiring less drilling, powder and general work, the per cubic yard cost for excavation of the timbered portion is usually materially less than for the untimbered, so that notwithstanding the larger required area of cross-section for the latter, the per lineal foot cost of excavation for timbered tunnel may be no more or even less than for the untimbered portions.

An excellent illustration of the above mentioned condition is to be found in the data from the Elizabeth Tunnel (Appendix 8, page 223), from which it appears that the cost of excavation and mucking from the north drift, in broken, rotten granite requiring 96 per cent of timbering, was only $25.79 per lineal foot, as against $28.75 per lineal foot in generally hard and sound granite with 20 per cent of timbering.

In the Elizabeth Tunnel the relative areas of excavation to the prescribed lines for timbered and untimbered tunnels were respectively 113 and 135 square feet, or 4.2 and 5.0 cubic yards per lineal foot of tunnel.

The respective costs per cubic yard for excavation and mucking were therefore about $5.16 per cubic yard in the timbered, and rather more than $6.85 per cubic yard in the untimbered tunnel.

This generally occurring difference in the excavation cost of these two classes of work has been taken into account in the assumption of unit prices, as shown in the following table. The difference naturally should be greater for the hard, massive rocks of igneous origin, than for the softer and more easily worked rocks of the sedimentary formations.

TABULATION OF UNIT PRICES USED IN MAKING PRELIMINARY ESTIMATE OF COST OF TUNNELS ON HETCH HETCHY PROJECT.

ITEMS.	Diameter, 6 feet.	FOR 200 MILLION GALLON AQUEDUCT, 10 FEET DIAMETER.					12.8 FEET DIAMETER	
	Three tunnels, total length about 2.3 miles, through San Bruno sandstone and other hard rocks of Franciscan series. Dry. 50% timbered.	*San Miguel Tunnel*—About 1,000 feet through jasper, a very hard rock, somewhat broken. 30% timbered. Very little water.	*San Bruno Tunnel*—About 4 miles through hard sandstone and schist of Franciscan series. 60% timbered. Deep shaft and long haul.	*San Andreas Tunnel*—About 3,500 feet through Merced sands; probably shield work; little water; heavy lining.	*San Andreas Tunnel*—About 5.8 miles through Franciscan sandstones and serpentine; considerably fractured; probably 70% timbered. Little water.	*Redwood Tunnel*—San Bruno standstone and serpentine. Little water; shattered. 70% timbered.	*Mission Pass Tunnel*—Sandstones, schist and shales; some massive soft sandstone. 60% to 70% timbered.	*San Antonio Tunnel*—60% timbered; little water; soft sandstone, etc. Worked from portals.
TIMBERED TUNNEL.								
Timbering and dry packing, per lineal foot	$4.00	$6.00	$6.00	$6.00	$6.00	$6.00	$6.50	$6.50
Excavation, per cubic yard	6.50	5.00	4.25	1.50	4.50	4.25	3.40	3.50
Concrete, 1:2½:5, per cubic yard	6.60	6.50	6.60	6.65	6.65	6.60	6.75	6.75
Cement, per barrel	1.70	1.70	1.75	1.80	1.80	1.80	1.90	1.90
Miscellaneous	2.50	3.25	3.50	3.50	3.50	3.50	3.50	3.50
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	.15	—	1.50	—	1.30	.65	.80	.40
Total for tunnel, per lineal foot	-$24.30	*$40.20	*$38.70	§$26.00	*$39.70	*$39.20	†$46.80	°$43.95
UNTIMBERED TUNNEL.								
Excavation, per cubic yard	$8.00	$6.50	$5.25	—	$5.00	$5.00	$3.80	$4.00
Concrete, 1:2½:5, per cubic yard	6.60	6.50	6.60	—	6.65	6.60	6.75	6.75
Cement, per barrel	1.70	1.70	1.75	—	1.80	1.80	1.90	1.90
Miscellaneous	2.00	3.00	3.20	—	3.20	3.00	3.20	3.20
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	.10	—	1.10	—	.95	.30	.50	.30
Total for tunnel, per lineal foot	$16.15	$30.95	$27.70	—	$26.65	$27.60	$32.50	$31.30
Length assumed as timbered	50%	30%	60%	100%	70%	70%	70%	60%
After giving proper weight to assumed length of timbered and untimbered sections, AVERAGE PRICE PER LINEAL FOOT	$20.25	$33.75	$34.30	$26.00	$35.80	$34.45	$42.50	$38.90

**6-foot tunnel, light section of concrete lining.
§10-foot circular tunnel through sand, concrete lining 16 inches thick.
*10-foot tunnel, light section of concrete lining.
†12.8-foot tunnel, medium section of concrete lining because under considerable head.
°12.8-foot tunnel, light section of concrete lining.
‡2.8-foot tunnel, heavy section of concrete lining, because under heavy outside pressures.

TABULATION OF UNIT PRICES USED IN MAKING PRELIMINARY ESTIMATE OF COST OF TUNNELS ON HETCH HETCHY PROJECT—Continued.

ITEMS.	VALLE TUNNEL, 12.8 FEET DIAMETER.				TESLA TUNNEL, 12.8 FEET DIAMETER.			
	Santa Margarita sandstone. Soft and sound; little water. Same as San Antonio, but all shaft work.	Pliocene gravels. Wet. 100% heavily timbered. Deep shafts.	Franciscan formation. Sandstone, shale and schist, fractured. Wet. 80% timbered. Deep shafts and long hauls.	Chico and Knoxville formations. Soft sandstone and clays. Wet. 80% timbered. Deep shafts and long haul.	Chico formation, same as previous tunnel, except allowance for overhaul and shaft hoisting.	Franciscan. 11 miles. Fractured shales, sandstone, some serpentine. Very wet at Mile 72. 80% timbered. Deep shafts and long haul.	Santa Margarita formation, 3.5 miles. Soft and sound standstone. Little water. 60% timbered.	Pliocene gravels. Four miles. Drained, but some water. 100% timbered.
TIMBERED TUNNEL.								
Timbering and dry packing, per lineal foot	$6.50	$8.50	$7.50	$7.50	$7.50	$8.00	$7.50	$7.50
Excavation, per cubic yard.	3.50	2.50	4.00	3.30	3.30	4.00	3.50	2.25
Concrete, 1:2½:5, per cubic yard. .	7.20	7.20	7.30	7.30	7.30	7.20	7.20	6.90
Cement, per barrel	2.20	2.20	2.30	2.30	2.30	2.20	2.20	2.10
Miscellaneous	3.50	5.00	4.00	4.00	4.00	4.00	3.50	3.00
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot.	1.70	2.50	2.85	3.85	2.95	3.75	2.50	1.60
Total for tunnel, per lineal foot.	°$46.00	‡$52.50	†$55.50	†$51.70	†$50.80	†$56.70	$47.80	‡$40.50
UNTIMBERED TUNNEL.								
Excavation, per cubic yard.	$4.00	—	$4.50	$4.20	$4.00	$4.50	$4.00	—
Concrete, 1:2½:5, per cubic yard. .	7.20	—	7.30	7.30	7.30	7.20	7.20	—
Cement, per barrel	2.20	—	2.30	2.30	2.30	2.20	2.20	—
Miscellaneous	3.25	—	3.70	3.70	3.70	3.70	3.25	—
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot.	1.35	—	2.40	3.00	2.30	2.90	2.00	—
Total for tunnel, per lineal foot.	$32.75	—	$39.50	$38.35	$36.50	$40.20	$33.40	—
Length assumed as timbered.	60%	100%	80%	80%	80%	80%	60%	100%
After giving proper weight to assumed length of timbered and untimbered sections, AVERAGE PRICE PER LINEAL FOOT	$40.70	$52.50	$52.20	$49.05	$47.95	$53.40	$42.05	$40.50

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*10-foot tunnel, light section of concrete lining.

†12.8-foot tunnel, medium section of concrete lining because under considerable head.

°12.8-foot tunnel, light section of concrete lining.

‡12.8-foot tunnel, heavy section of concrete lining, because under heavy outside pressures.

TABULATION OF UNIT PRICES USED IN MAKING PRELIMINARY ESTIMATE OF COST OF TUNNELS ON HETCH HETCHY PROJECT—Continued.

ITEMS.	DRY CREEK TUNNEL, 12.8 FEET DIAMETER.			MOCCASIN PEAK TUNNEL, 10 FEET DIAMETER.				
	Porphyrite. Eight miles. A hard crystalline formation, tough and hard to drill. 10% timbered. Light section. No water.	Mariposa clay, slate and sandstone. The slate is a bad, blocky formation, due to cross-jointing. 80% timbered.	Amphibolite, one-half mile. A massive schistose rock, hard and stable. 10% timbered. Dry.	Amphibolite, a greenish, hard, massive schistose or fibrous rock. 10% timbered. Little water.	Serpentine, an altered igneous rock, hard to drill, but usually much jointed, more massive in this belt than common. 75% timbered.	Porphyrite, a hard crystalline rock, same as in Dry Creek tunnel. 10% timbered. Little water.	Mariposa slates. Clay, slate and fine-grained sandstone; steep dip to southwest; generally unsound formation. 80% timbered.	Porphyrite. A hard crystalline formation same as in Dry Creek tunnel. 10% timbered. Some water at seams.
TIMBERED TUNNEL.								
Timbering and dry packing, per lineal foot	$8.00	$8.00	$8.00	$6.50	$6.50	$6.50	$6.50	$6.25
Excavation, per cubic yard	4.80	3.60	4.60	4.90	4.75	5.00	3.90	5.00
Concrete, 1:2½:5, per cubic yard	7.40	7.40	7.40	7.90	7.90	7.90	7.90	7.70
Cement, per barrel	2.40	2.40	2.40	2.75	2.75	2.75	2.75	2.60
Miscellaneous	3.60	3.60	3.60	3.70	3.70	3.70	3.70	3.70
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	1.70	1.60	1.40	1.05	1.40	2.55	.40	1.85
Total for tunnel, per lineal foot.	*$56.35	†$51.45	*$54.70	*$43.60	*$43.25	*$45.50	†$42.75	*$44.30
UNTIMBERED TUNNEL.								
Excavation, per cubic yard	$5.40	$4.00	$5.20	$5.60	$5.20	$5.60	$4.30	$5.70
Concrete, 1:2½:5, per cubic yard	7.40	7.40	7.40	7.90	7.90	7.90	7.90	7.70
Cement, per barrel	2.40	2.40	2.40	2.75	2.75	2.75	2.75	2.60
Miscellaneous	3.35	3.35	3.35	3.40	3.40	3.40	3.40	3.40
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	1.35	1.30	1.10	.80	1.05	1.90	.30	1.40
Total for tunnel, per lineal foot.	$40.85	$35.55	$39.50	$29.65	$28.45	$30.75	$28.00	$30.50
Length assumed as timbered	10%	80%	10%	10%	60%	10%	80%	10%
After giving proper weight to assumed length of timbered and untimbered sections, AVERAGE PRICE PER LINEAL FOOT	$42.40	$48.30	$41.00	$31.05	$37.30	$32.20	$39.80	$31.90

*10-foot tunnel, light section of concrete lining.

†12.8-foot tunnel, medium section of concrete lining because under considerable head.

°12.8-foot tunnel, light section of concrete lining.

‡12.8-foot tunnel, heavy section of concrete lining, because under heavy outside pressures.

TABULATION OF UNIT PRICES USED IN MAKING PRELIMINARY ESTIMATE OF COST OF TUNNELS ON HETCH HETCHY PROJECT—Continued.

ITEMS.	GROVELAND TUNNEL, 10 FEET DIAMETER.						Canyon Tunnel.	200 MIL. GAL. TUNNEL TO LAKE CHABOT. 10 ft. diam.			
	Calaveras quartzite, mica, schist and clay slate, at three separate points. Not hard to work, but will require 70% timbered. Probably wet at contact planes.			Granite, in two sections. First section is coarse-grained and easier to work than the hard, fine-grained rock of second section. 10% timbered. Wet at seams.		Andesite tuff, soft porphyrite rock. Easily worked. Probably considerable water at seams. 20% timbered.	*Canyon Tunnel*—Granodiorite in this locality is a very hard and massive, fine-grained gray rock. 5% timbered. Dry.	Sandstones and shales of Santa Margarita and Monterey formations, variable in soundness and hardness. 70% timbered. Little water.	Knoxville shales and sandstones, thin beds, loose ground where dip is light. 70% timbered. Some water.	Serpentine for two miles, generally a bad, treacherous rock to tunnel through. 80% timbered. Some water.	Knoxville shale and sandstone, 1½ miles near Haywards, thinly bedded and rather unsound. 70% timbered.
TIMBERED TUNNEL.											
Timbering and dry packing, per lineal foot	$6.25			$6.25		$6.25	$6.25	$6.00	$6.00	$6.00	$6.00
Excavation, per cubic yard	3.90			$4.80	$5.50	3.00	6.00	3.70	3.90	4.70	3.90
Concrete, 1:2½:5, per cubic yard	$7.70	7.80	$7.95	7.80	8.00	8.10	8.20	6.70	6.70	6.65	6.65
Cement, per barrel	2.65	2.70	2.75	2.70	2.85	2.90	3.00	1.85	1.85	1.80	1.80
Miscellaneous	3.70			3.70		3.70	3.80	3.50	3.50	3.50	3.50
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	3.20	2.15		1.85	1.35	.90	.20	.70	1.35	1.15	
Total for tunnel, per lineal foot	*$40.70	39.80	37.85	*$43.55	46.45	*$34.90	*$47.90	*$35.55	*$37.10	*$40.45	*$35.70
UNTIMBERED TUNNEL.											
Excavation, per cubic yard	$4.40			$5.50	$6.50	$3.30	$7.50	$4.20	$4.40	$5.20	$4.40
Concrete, 1:2½:5, per cubic yard	$7.70	7.80	$7.95	7.80	8.00	8.10	8.20	6.70	6.70	6.65	6.65
Cement, per barrel	2.65	2.70	2.75	2.70	2.85	2.90	3.00	1.85	1.85	1.80	1.80
Miscellaneous	3.40			3.40		3.40	3.50	3.20	3.20	3.20	3.20
Add for long haul and deep shaft hoisting on excavation, and concrete, per lineal foot	2.40	1.60		1.40	1.00	.65	.15	.50	1.00	.85	
Total for tunnel, per lineal foot	$26.70	25.95	24.45	$29.85	33.25	$21.10	$36.30	$23.25	$24.50	$27.30	$23.50
Length assumed as timbered	70%			15%	5%	20%	5%	70%	70%	80%	70%
After giving proper weight to assumed length of timbered and untimbered sections, AVERAGE PRICE PER LINEAL FOOT	**$36.50**	**35.95**	**33.85**	**$31.90**	**33.90**	**$23.85**	**$36.90**	**$31.90**	**$33.30**	**$37.80**	**$32.05**

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*10-foot tunnel, light section of concrete lining.

†12.8-foot tunnel, medium section of concrete lining because under considerable head.

°12.8-foot tunnel, light section of concrete lining.

‡12.8-foot tunnel, heavy section of concrete lining, because under heavy outside pressures.

By way of confirming the adequacy of the assumed unit prices to cover the cost of the proposed work under the conditions stated, reference is made to the following statements obtained mainly from published reports, of the cost of tunnels actually constructed. What follows is merely intended to supplement the Los Angeles data already presented, and which because of its more pertinent application has been used as the basis for our tunnel estimates.

Examples of Small Tunnels

Lincoln Mine, Sutter Co., Cal.—5 feet by 8 feet, 1,175 feet long, through "greenstone" (porphyrite?) and hard slate; drift at about 1,950-foot level. Wages: Miners $2.75 per day, car men $2.50 for ten-hour shifts.

Cost per foot excavation without lining	$5.37
Cost per cubic yard of excavation	4.26 (approx.)

Note: For the assumed present rates of wages these costs should be about one-fifth greater.

Huntley Tunnel, Montana.—7 by 9-foot tunnel, 1,200 feet long, in sandstone; good material.

Cost per foot excavation	$ 7.00
Contract price per foot concreted	12.00
Cost per cubic yard of excavation	3.00 (approx.)

Santa Ana Canal, California.—Three 6-foot circular tunnels, 4,000, 1,600 and 1,400 feet long. Contract work.

Price for excavation in rock	$ 9.25 per cu. yd.
Price for excavation in shale	5.25 " "
Price for excavation in boulders	3.50 " "

Cost of excavating and lining 220 feet of rock tunnel. 13.28 per foot.

Yakima Project, Washington (U. S. Reclamation Service).—*Columnar tunnel*, 7 feet inside diameter, 1,200 feet long, excavated through basalt and volcanic debris. Lined with timber. Work was done by contract.

Tunnel excavation	$12,120, or $10.10 per foot.
Timber lining	466
	$12,586, or $10.50 per foot.

Stated to be actual cost, exclusive of the contractor's profit.

Note: Estimating the excavation to run 1.85 cubic yards to the foot, the cost of this basalt was about $5.45 per cubic yard.

Examples of Medium Size Tunnels

Corbett Tunnel, Shoshone Project, Wyoming (U. S. Reclamation Service).—10.75 feet by 11.5 feet, 17,355 feet long; horseshoe section with net area about 104 square feet. Tunnel is lined with concrete throughout. Work was done between 1905 and 1908. Material mainly sandstone, with some shale and clay. Worked from two portals and three adits. Started under contract at $33.00 per foot, but after nine months' work the contract was annulled and the work completed by the Reclamation Service by day labor.

Total cost for completed tunnel, $66.60 per foot.

Note: Two barrels of cement were used per lineal foot of lining, or at the rate of about 1.5 cubic yards concrete, which indicates the use of 10 to 20 per cent thicker lining than specified for the Hetch Hetchy tunnels of approximately the same size.

Salt River Project, Arizona (U. S. Reclamation Service).—A number of concrete-lined tunnels, aggregating 9,700 feet in length, were constructed on the power canal. Work done by day labor force of U. S. Reclamation Service.

Tunnel No. 2—Sectional area 80.5 square feet; 124 lineal feet through hard conglomerate, drilled by hand.

Excavation cost for labor and materials	$8.98 per foot.
Excavation cost for labor and materials	3.00 per cu. yd.

Tunnel No. 13—Sectional area 110.2 square feet; 155 lineal feet through hard sandstone, by hand drilling.

Excavation cost for labor and materials	$19.64 per foot.
Excavation cost for labor and materials	4.93 per cu. yd.

Truckee-Carson Project, Nevada (U. S. Reclamation Service).—Three concrete lined tunnels, aggregating 2,725 lineal feet; size 12 feet by 12 feet, with arched roof. Lining 4 inches in the bottom, 12-inch sides and 16 inches in arch. Nature of material driven through not stated. The work was done by contract.

The actual cost is stated as $114,000, in round numbers, or approximately $42.00 per lineal foot. This includes cost of cement at $2.55 per barrel, and overhead charges, but contains no allowance for contractor's profit.

Klamath Project, Oregon and California (U. S. Reclamation Service).—Tunnel 13.5 feet wide by 14.4 feet high, with arched roof; length 3,290 feet, lined throughout with concrete of minimum thickness of 8 inches. Excavation was done from both portals and three shafts; 2,200 lineal feet required timbering.

Excavation cost	$65,700,
or approximately $2.45 per cubic yard.	
Concrete lining	80,380,
or about $24.40 per cubic yard for minimum thickness.	
Timber	7,000,
or $36.80 per 1,000, or $3.20 per lineal foot.	
	$153,080,
or $46.50 per lineal foot.	

This is stated to be actual cost of work, not including profits to the contractor.

Note: The cost for concrete lining is very high, but is partly accounted for by high cost of cement, and the remainder probably by an unusual amount of over-breakage in the excavation, which appears to have been in soft material, about two-thirds of which required timbering.

Examples of Large Size Tunnels

Such as single-track railroad tunnels, about 18 feet by 24 feet inside dimensions, with excavation quantities running from 17 to 18 cubic yards per lineal foot.

A Southern Pacific Railroad tunnel in the Sierras, 17.25 cubic yards per foot, 2,061 feet long, built by contract.

Total excavation cost, labor and materials	$67.64 per foot.
Total timbering cost, labor and materials	55.45 per M.

The contract price for building the concrete arch and headwalls at the portals was $12.00 per cubic yard for 1,000 cubic yards, with cement at $2.31 per barrel.

Excavation cost, including a supposed profit to contractor, was $3.92 per cubic yard.

Another single-track tunnel in the Sierras, 1,136 feet through mixed materials, mostly hard to work; prescribed section of excavation 17.25 cubic yards per lineal foot.

Total excavation cost, labor and materials	$50.41 per foot.
Total timbering cost, labor and materials	54.49 per M.
Total concrete at portals, cost, labor and materials	10.59 per cu. yd.

Excavation cost, including a supposed profit to contractor, was $2.92 per cubic yard.

Note: In the two preceding instances the cost of concrete would naturally be greater than for tunnels of smaller size, lined full length, because the short lengths lined would have to bear the entire cost of the forms and installation of special plant, and would also be subject to a less economical method of placing the concrete than if the work had been on a large scale.

ADDITIONAL DATA ON UNIT COSTS

Some records relating to the cost of the double-track tunnels for the Bay Shore Railway, built by contract with the base rate of $2.25 per ten-hour day for common labor, show as follows:

Excavation cost for Potrero Tunnel, including labor, teams, explosives, tools, plant and tracks, for assumed maximum prescribed section of 32.17 cubic yards, per lineal foot	$2.87 per cu. yd.
Excavation cost for Orphan Asylum Tunnel, including labor, teams, explosives, tools, plant, tracks, for assumed maximum prescribed section of 32.17 cubic yards, per lineal foot	3.75 " "
Timbering Potrero Tunnel, labor and materials	1.10 " "
Timbering Potrero Tunnel, labor and materials	35.60 per foot.
Timbering Orphan Asylum Tunnel, labor and materials	.76 per cu. yd.
Timbering Orphan Asylum Tunnel, labor and materials	24.59 per foot.
Concrete cost Potrero Tunnel, including labor, materials, forms, tools, plant and track	7.11 per cu. yd.
Concrete cost Orphan Asylum Tunnel, including labor, materials, forms, tools, plant and track	10.07 " "
Concrete cost Sierra Point Tunnel, including labor, materials, forms, tools, plant and track, with cement at $3.00 per barrel	9.19 " "

Contract prices for single-track tunnels on the Western Pacific Railroad in its construction through the mountains of California were, in general:

Excavation tunnel in rock	$ 3.50 per cu. yd.
Enlarging for lining	3.00 " "
Timbering, in place	40.00 per M.
Concrete in sidewalls	7.50 per cu. yd.
Concrete in arch	11.00 " "
Dry packing	3.50 " "

Note: The road was built in 1905-1908, when the rates for labor and materials were approximately the same as now.

Estimates for Minor Structures

Special structures such as gate-houses, bridges at river crossings, shafts, surge tanks, diverting dams, blow-offs for pipe lines, etc., have been individually considered, and the cost computed on approximate quantities estimated from data obtained by actual surveys or derived from the topographical maps and a field inspection.

Unit Prices for Grading and General Work

These have been based on the average contract prices as given below, paid by the Western Pacific and Southern Pacific Railroads for mountain work in California, the same having been increased in the estimate according to my personal judgment to fit local conditions and a somewhat higher scale of wages.

Character of work and the average prices paid by two railway companies on large contracts in California under conditions similar to those on this work	Western Pacific R. R., 1907.	Southern Pacific R. R., 1911.
Clearing, per acre	$75.00	
Earth, per cubic yard	.18	$ .16 to $ .22
Cemented material, per cubic yard	—	.40 " .45
Soft rock and loose rock, per cubic yard	.45	.45 " .50
Solid rock, coarse granite, etc., per cubic yard	.70	.85 " 1.00
Hard rock, per cubic yard	—	1.00 " 1.15
Over-haul over 800 feet free haul by teams, per 100 feet	.01	.01
Over-haul over 2,000 feet free haul by train, per 1,000 feet	.012	
Retaining walls in mortar, per cubic yard	6.00	
Retaining walls laid dry, per cubic yard	4.50	
Paving, per cubic yard	3.00	
Rip-rap, per cubic yard	1.50	
Plain concrete, per cubic yard	7.50	9.00 " 9.50
Wagon over-haul over 5 miles on concrete materials, each mile, per ton	.35	
Shaft excavation, 12 feet by 18 feet, clear inside timbers, per cubic yard	7.50	
Shaft timbering, per 1,000 feet	55.00	
Piles, delivered, per lineal foot	.30	
Piles, driven, below cut-off, per lineal foot	.25	
Rough lumber, at Oakland, per 1,000 feet	—	15.50 " 17.00
Dimension timber, at Oakland, per 1,000 feet	—	16.00 " 21.00

Wages for Common Labor

In California there is a lively demand for common labor during the wheat harvesting and fruit picking seasons, which tends to raise wages above the normal level during those periods, so that in general they fluctuate during the year from $2.25 to $2.75 per day for unskilled laborers. The highest rate is maintained for about one-third of the time.

In support of the adoption of $2.25 per day as the base rate of wages for this estimate, we have the following information from reliable sources:

On the extensive canal and tunnel work now in course of construction for the Oakdale Irrigation District the contractor was paying in July, 1912, from $2.25 to $2.50 per ten-hour day for common labor.

At the new dam on the north fork of the Feather River, 25 miles from the railroad, the Great Western Power Company is working a large force of men, and during July paid from $2.00 to $2.25 per ten-hour day for pick and shovel men, working above ground.

At the new dam of the Pacific Gas and Electric Company, on the Yuba River, the company is paying its common labor at the rate of $2.25 per nine-hour day.

Observations of men and of conditions in many construction camps prove that the men and the progress of the work can both be benefited by scrupulous attention to conditions affecting the housing, food and comfort of the men, with opportunity for wholesome recreation during the hours off duty, and that by these means the better class of labor can be attracted and held more strongly than by even 25 cents additional in the daily wage or an hour less in daily task, and it is assumed in the estimate of incidental costs that these matters will receive most careful attention. The site of this work is attractive.

The ruling rate paid by contractors working for the Southern Pacific Railroad is said to vary from $2.25 to $2.75 per ten-hour day, according to the time of year.

On the Los Angeles Aqueduct, the day laborers employed by the city receive $2.25 to $2.50 per eight-hour day.

If the Hetch Hetchy work should be built under contracts which impose no conditions as to the wages to be paid, it is probable that the above-named rates would not in the long run be greatly exceeded, and that an average of $2.25 per eight-hour day is a fair and liberal assumption.

If, however, the work to be done outside of city limits is to be subjected to the same conditions as to rates of wages, length of working day and the domination of political interests which are prone to prevail in municipal work, then the assumed rate of $2.25 per eight-hour day will be at least 75 cents too low; and, since in this class of work the labor account will be fully as much or more than the amount to be expended for plant, materials, etc., it is quite conservative to assume that the estimated cost of construction, exclusive of administration, engineering and plant, must be increased by about 20 per cent.

Arrangement of the Estimate

Since in the problem of a new and ample water supply for San Francisco and adjacent communities, one question of prime importance concerns the comparative cost of delivering water from the Tuolumne River, or other sufficient and suitable source, into some capacious storage reservoir located near the city, it is desirable that this estimate should be so arranged that it can be placed in comparison with other projects which have been suggested for bringing a new and large supply from a distance.

By raising the Crystal Springs Dam to the height for which it originally was designed, a reservoir of large storage capacity will be created within easy reach of the city, and this site appears to be the most favorable one to utilize for a terminal reservoir on the west side of San Francisco Bay. As to nearness to the center of population to be served, it compares favorably with possible reservoirs of large capacity on the east side of the bay, which might serve equally well or better for terminals of the main aqueducts of other projects.

Because the methods and cost of the final distribution to the several districts to be supplied from any chosen terminal, or central storage reservoir, under different projects are matters subject to differences in the location of the terminal reservoirs, also to other considerations which cannot now be definitely decided, the portion of the estimate which relates to the delivery of the Tuolumne supply to the central storage reservoir at Crystal Springs will be kept distinct from that pertaining to the cost of the smaller extensions required to connect this large reservoir with the service reservoirs and mains of the several communities which may eventually be comprised in the metropolitan water district.

The following estimate therefore begins with the Fourth Division, starting at the south end of the enlarged Crystal Springs Reservoir, where the main conduit from the Tuolumne River can properly be regarded as terminating. The estimates for the extensions to San Francisco and for the branch aqueduct to Lake Chabot, to supply Oakland and vicinity, will be taken up farther on, and will be regarded as supplementary to the estimate of cost of the main line to Crystal Springs Reservoir.

Fourth Division, Crystal-Irvington

The work comprised in this division includes the open cut necessary for a connection with Crystal Springs Lake at its south end, and extends to the beginning of the portal cut about 250 feet west of the Irvington Gate House. Length, 22.4 miles.

The above work is subdivided and estimated as follows:

(1)	Open channel outlet from terminal Gate House into Crystal Springs Reservoir, mixed materials, rock, hard-pan, earth with some wet digging and rather inconvenient disposal of waste material— 56,000 cubic yards unclassified material, at 85 cents	$47,600
(2)	Gate House at Crystal Springs Reservoir. Excavation, foundations, superstructure, gates, screens, etc., complete	12,500
(3)	Two double compartment shafts, at mile 26.6,[*] about 200 feet deep, at mile 27.4, 100 feet deep— 300 lineal feet total depth of shafts, at $100	30,000
(4)	Pressure tunnel from Gate House to west end of pipe across Santa Clara Valley, mile 25.5 to mile 28.5— 15,800 lineal feet, 10 feet diameter tunnel, 70 per cent timbered, lined with concrete for entire length, at $34.50	545,100
	The location of this tunnel was not inspected, but it is assumed that the same hard rock, mainly San Bruno sandstone, and	
	Carried forward	$635,200

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[*] Where the location of a structure is indicated by the mile, it refers to the distance from San Francisco City Hall, measured along the aqueduct line, but because of a change from the first location, the distance now is more correctly 1.6 miles shorter than indicated.

Brought forward $635,200

some serpentine found farther north in this ridge will be found here. Probably much shattered in places by proximity to San Andreas fault. No unusual difficulties from water or heavy ground are apprehended.

(5) Portal cut and pipe connections at the east end of tunnel. Two lines 6.75 feet steel pipe will eventually be laid across the Santa Clara Valley, and a special section of tunnel will be required for a short distance to permit the pipes to be inserted far enough to make a safe water-tight connection with the tunnel lining. Two pipes will be inserted for that portion of the tunnel which must be refilled with concrete.

400	cubic yards earth excavation, at 25 cents	$ 100
1,000	cubic yards hard rock excavation, at $1.00	1,000

Special section of pipe tunnel, 22 feet by 10 feet, 70 per cent timbered, no lining.

220	lineal feet excavation, at $43.00 . .	9,460
175	cubic yards concrete refill, at $7.00	1,230

(6) Bay Head Siphon, 19.1 miles of steel pipe across Santa Clara Valley, via Dumbarton Point. Pipe 6.75 feet diameter, cement lined inside to thickness of 1½ inches, making net diameter 6.5 feet. The distance across the valley is 100,600 lineal feet, to which 200 feet must be added for dip of pipe across valley and at channel crossing, and for second pipe at the tunnel ends, making total length of pipe 100,800 lineal feet on the present map location, but it appears feasible by a slight change of location to shorten this by about 740 feet, making length estimated on 100,060 lineal feet.

Of the above total length—

74,840 lineal feet will be on firm dry ground.

8,730 lineal feet will be over marsh flats that are slightly flooded by extreme high tides.

10.560 lineal feet on tidal and wholly submerged flats with from 5 to 8 feet of water at mean high tide.

Carried forward $646,990

Brought forward $646,990

4,880 lineal feet of submerged pipe at main channel, including 130 feet extra for dip.

1,050 lineal feet of pipe across secondary channels with depth of 8 to 20 feet of water at high tide, which it will probably be cheaper to cross on a concrete pile trestle rather than with embankment. The location noted on the map crosses Newark Slough, which is navigable, therefore requiring a second length of submerged siphon. It seems possible to eliminate this crossing without any increase in cost by locating the pipe line about 5,000 feet to the south. The estimate has been made on the suggested new location. This pipe has been further classified as follows:

2,970	lineal feet ¼-inch shell, dry land, at $11.10	$ 33,000
2,130	lineal feet ⅜-inch shell, dry land, at $14.00	29,800
5,280	lineal feet 7/16-inch shell, dry land, at $15.70	82,900
32,210	lineal feet 15/32-inch shell, dry land, at $16.50	531,500
15,100	lineal feet ½-inch shell, dry land, $17.40	262,700
*17,150	lineal feet ½-inch shell, on low embankment on dry land, at $16.60	284,700
* 8,730	lineal feet ½-inch shell, on low embankment on marsh flats, at $16.60	144,900
*10,560	lineal feet ½-inch shell, on high embankment on submerged tidal flats, at $16.60	175,300
* 1,050	lineal feet ½-inch pipe, on concrete pile trestles across sloughs, at $16.60	17,430
* 4,880	lineal feet 17/32-inch pipe, main channel crossing, at $17.50	85,400

An inspection of the marsh land showed it to be fairly firm ground, capable of bear-

Carried forward $2,294,620

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*The prices for these items are exclusive of excavation and filling. The extra allowances for embankment and special work are made below.

Brought forward $2,294,620

ing the weight of an embankment without much settlement. Road and railroad embankments on these flats are built to a minimum height of between 3 and 4 feet above the surface of the marsh. This appears to be a safe elevation for the bottom of the pipe. The general level of the marshes has been assumed as 8 feet above mean low water. The extreme range of the tides at Ravenswood is 10.5 feet, but ordinarily only 7 feet. The mean height of the higher high waters is +8.5, and the bottom grade of the pipe has been placed at +12.

The embankment is assumed to be 8 feet wide, with 1 on 1½ slopes, and 18 inches cover over the pipe. The submerged flats are said to be soft mud for a depth of 5 or 6 feet, and then hard clayey bottom. It is proposed to build the embankment as far as possible by dredging from both sides and depositing the material in the center. Earth can be handled very cheaply by this method, sometimes as low as 5 cents per cubic yard. For the kind of material to be handled at this point 10 cents per cubic yard, exclusive of contractor's profit, is certainly a liberal allowance.

The embankment to be built by dredging extends from mile 35.6 to 40.35, or 25,090 lineal feet, less 5,800 feet for main channel and bridges.

19,290	lineal feet embankment built of dredged material, 575,300 cubic yards, at 10 cents	$ 57,530
17,150	lineal feet low embankment on dry land, scraper work, 107,300 cubic yards, at 15 cents	16,100
4,750	lineal feet trench dredged across main channel, deep water and extra work in disposal of material, 66,000 cubic yards, at 20 cents	13,200
Concrete casing for 4,800 lineal feet—		
4,000	cubic yards built on land, at $7.00	28,000
12,100	cubic yards built under water, at $14.00	169,400
For piling, rental of tugs and scows, and submarine work for placing pipe		70,000
Carried forward		$2,648,850

Brought forward $2,648,850

For 1,050 lineal feet of bridges across secondary channels, about 60-foot spans of self-supporting pipe on concrete pile piers, allow as follows:

1,050 lineal feet pipe with 1/16-inch extra thickness of shell, at $2.00	2,100
18 piers, average height 35 feet, with piles driven 20 feet into ground:	
36 piles, 3 feet diameter, in place, at $140.00	5,040
17 piles, 2 feet diameter, in place, at $78.00	5,620
Caps, bracing, etc., for 18 piers	5,100
Rental of tugs and scows, extra work placing pipe, etc.	3,500
Allowance to cover cost of manholes, blowoff and the structure and bailing equipment for emptying siphon at the channel crossing	13,800
Construction cost of the Crystal-Irvington Division, exclusive of general administration, heavy plant and contractor's profit	$2,684,000

Fifth Division, Irvington-Calaveras

The work in this division comprises that part of the main aqueduct extending from the entrance to the portal cut of the Mission Pass Tunnel, at mile 47.55 to the junction of the Calaveras branch, at mile 50.8; also the branch pipe line and structures necessary for annexing the supply from the new Calaveras Reservoir proposed by the Spring Valley Water Company. Length of main aqueduct, 3.25 miles; length of branch about 1.3 miles.

The principal items of cost will be:

(1) Portal cut and pipe connections to Mission Pass Tunnel:	
400 cubic yards earth excavation, at 25 cents	$ 100
1,000 cubic yards rock excavation, at $1.00	1,000
Special section of pipe tunnel 22 feet by 10 feet, 70 per cent timbered, no lining, estimated as follows:	
220 lineal feet pipe tunnel, at $43.00 . . .	9,460
260 cubic yards concrete refill, at $7.00 . .	1,820
Carried forward	$12,380

Brought forward	$12,380
310 lineal feet of 6.75 feet steel pipe in portal cut, plus 60 feet of duplicate pipe, ¼-inch shell, at $10.30	3,200

(2) Irvington Gate House, at mile 47.6. This is the junction point for future branch lines to Lake Chabot and San Jose. The gates are designed to be located in a shaft, which will serve the purpose of a surge tank.

An ornamental superstructure will probably be desired for this conspicuous location.

The tunnel bottom is at elevation 280.

Maximum hydraulic grade with one pipe, elevation 343.

Maximum hydraulic grade when two pipes are in operation, elevation 410.

140 lineal feet shaft 12 feet by 42 feet inside, with concrete lining averaging 2 feet thick.	
740 cubic yards shaft excavation, at $10.00	7,400
3,260 cubic yards shaft excavation, at $5.00	16,300
120 lineal feet shaft timbering, at $27.00	3,240
1,400 cubic yards concrete lining, at $7.00	9,800
Gate house foundations and superstructure gates, special fittings and miscellaneous . .	18,000

(3) Two shafts, double compartment, 60 and 210 feet deep, at miles 48.1 and 50 respectively. These shafts are readily accessible by good road and a three to four-mile haul from the railroad stations at Irvington and Sunol.

270 lineal feet timbered shafts at $100.	27,000

(4) Portal cut and special section of tunnel for pipe connection at east end of Mission Pass Tunnel. The maximum head at this point may eventually be as much as 170 feet head, and in order to get under heavy cover for the pressure tunnel the pipes must be inserted about 250 feet.

800 cubic yards earth excavation, at 25 cents	200
1,800 cubic yards rock excavation, at $1.00	1,800
Carried forward	$99,320

Brought forward	$99,320

Special section of pipe tunnel 26 feet by 12 feet, 100 per cent timbered, no lining:

250 lineal feet pipe tunnel, at $55.00 . .	13,750
400 cubic yards concrete refill, at $7.00	2,800

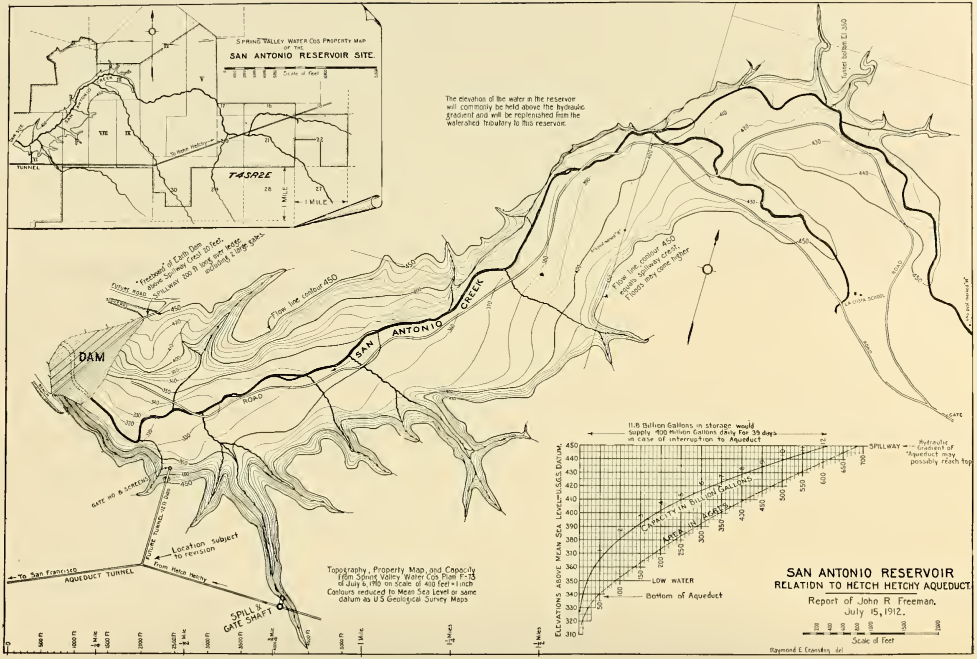
(5) Pressure tunnel from Irvington Gate House to Alameda Creek, at junction of Calaveras branch aqueduct. Mile 47.6 to 50.8, or 16,900 lineal feet of tunnel, 12.8 feet diameter, lined throughout with concrete. This tunnel will be entirely through sedimentary formations, of a varied character, consisting of interbedded shales and clays, broad belts of rather soft sandstone of quite massive character. The strike and the steep dip of the thinner beds are favorable to stability. Probably from 60 to 70 per cent of the length will require some timbering, not so much to hold up heavy ground as to protect the workmen from injury from the fall of loose fragments. The tunnel is situated at a high level, and from surface indications it is not thought that any very wet ground will be encountered. The longest stretch of tunnel will be two miles between the two shafts. Increase the thickness of lining because of high internal pressure.

11,800 lineal feet of timbered tunnel through thinly bedded clays, shales and sandstone, at $47.00	554,600
5,100 lineal feet of untimbered tunnel through thickly bedded sandstone, generally soft, but fairly sound, at $32.50	165,800

(6) Branch works to utilize Calaveras storage during early years. When main aqueduct is extended eastward to San Antonio, Valle and Hetch Hetchy, a pipe line about six miles long, drawing directly from the Calaveras reservoir, will probably be substituted for the cheaper works now proposed.

For the present the water will be carried in its natural channel for 4.7 miles to a suitable place for a low diversion dam, thence 1.3 miles farther by circular concrete pipe, 4 feet in diameter, and deliver into the main aqueduct at the east end of Mission Ridge tunnel. Pipe will be located

Carried forward	$836,270



SAN ANTONIO RESERVOIR
RELATION TO HETCH HETCHY AQUEDUCT.

Report of John R Freeman.
July 15, 1912.

Raymond E Cranston del

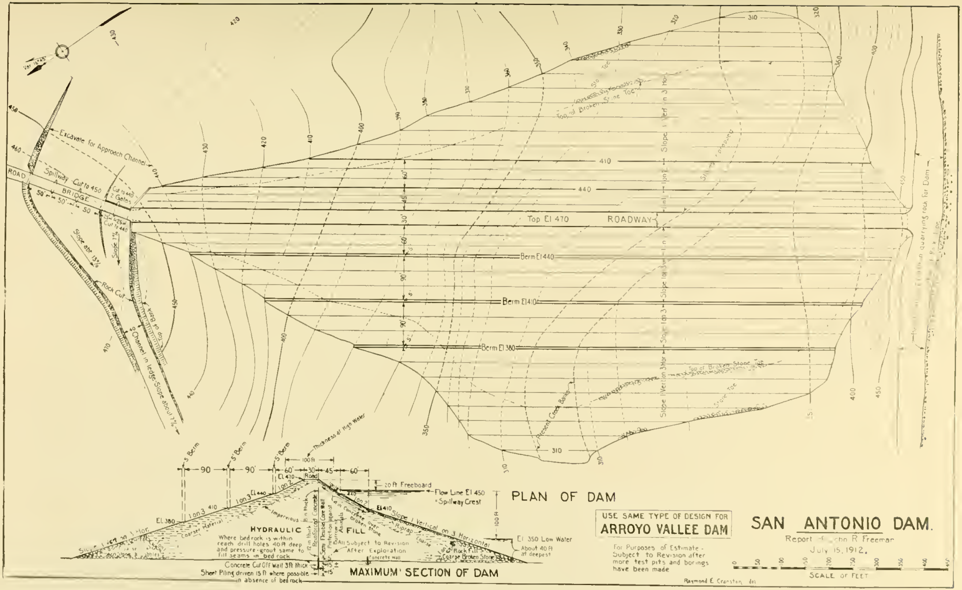
The elevation of the water in the reservoir will commonly be held above the hydraulic gradient and will be replenished from the watershed tributary to this reservoir.

Topography, Property Map, and Capacity from Spring Valley Water Co's Plan F-73 of July 6, 1910 on scale of 400 feet = 1 inch. Contours reduced to Mean Sea Level or same datum as U.S. Geological Survey Maps

"Freeboard" of Earth Dam above Spillway Crest 20 feet. SPILLWAY 200 ft long over ledge including 2 large gates.

Flow line contour 450 equals spillway crest. Floods may come higher

11.8 Billion Gallons in storage would supply 100 Million Gallons daily for 39 days in case of interruption to Aqueduct



USE SAME TYPE OF DESIGN FOR
ARROYO VALLEE DAM

For Purposes of Estimate -
Subject to Revision after
more test pits and borings
have been made

SAN ANTONIO DAM.

Report of John R Freeman
July 15, 1912.

Brought forward	$836,270
wholly on the floor of the valley, making very easy and cheap work.	
A concrete weir about 500 feet long across Alameda Creek, to divert water into pipe, with gatehouse, sluice, screens, etc., complete	12,000
6,860 lineal feet concrete pipe, 4 feet inside diameter, partly reinforced, including excavation and refill, all complete, at $4.40	30,200
Construction cost Irvington-Calaveras Division, exclusive of charges for general administration, heavy plant and contractor's profit	$878,500

Sixth Division, Calaveras-Antonio

This division includes the structures necessary to extend the main aqueduct from Calaveras Junction to a connection with the proposed San Antonio Reservoir of the Spring Valley Water Company's system, mile 50.80 to 52.75. Length of main aqueduct 1.95 miles, and of 10-foot branch tunnel and open cut, 0.2 miles.

The work to be done has been subdivided as follows:

(1) Steel pipe siphon, 9.0 feet diameter across Alameda Creek Valley, Mile 50.8 to 51.65; length, say 4,500 feet.

The working diameter of this pipe will be reduced to 8.75 feet net by the interior cement lining 1½ inches thick. The broad gravelly wash of Alameda Creek can be crossed most cheaply by carrying the pipe in deep trench under same, but in order to have the pipe easily accessible for repairs it is deemed wiser to adopt the more costly expedient of bridging the creek by supporting the pipe on concrete piers, spaced about 60 feet apart, and making the pipe self-supporting by a slight increase in thickness of shell. The required width of waterway is assumed as 260 feet. The maximum head to which the pipe will be subjected has been estimated as 180 feet.

Except the short, steep inclines at the two ends, the pipe will be laid across the smooth level floor of the valley, with easy digging through dry ground. About 1,000 feet of pipe will be laid above ground on low embankment.

This 4,500 feet length of pipe is estimated to cost as follows, with prices proportionately 10 per cent higher than for the Bay Head Siphon because being a smaller job it cannot be done so economically.

1,040 lineal feet 5/16-inch shell, including 200 feet of duplicate pipe at tunnel connections, at $15.00	$15,600
3,400 lineal feet 13/32-inch shell, at $18.25	62,100
260 lineal feet ⅝-inch shell, for bridge, at $27.00	7,000
Estimated cost of three piers and two abutments for pipe bridge over Alameda Creek	2,800
Extra allowance for pipe on embankment, 1,000 lineal feet, at $4.00	4,000
Blow-off, manholes and extras	1,000

(2) Portal cut and pipe connections at west end of San Antonio Tunnel:

800 cubic yards earth excavation, at 25 cents	200
1,800 cubic yards rock excavation, at $1.00	1,800
Special section of pipe tunnel, 26 feet by 12 feet, 100 per cent timbered, 150 lineal feet pipe tunnel, at $55.00	8,250
250 cubic yards concrete refill, at $7.00	1,750
Standpipe, gate chamber underground, and gates	8,000

(3) Pressure tunnel, pipe chamber, to connection with San Antonio Reservoir, mile 51.65 to 52.75, or 5,800 lineal feet of 12.8 feet diameter tunnel, lined full length with concrete.

This tunnel probably will run wholly through the soft and fairly sound sandstone beds of the Santa Margarita formation. It appears safe to say that not more than 60 per cent of the length will require to be timbered.

3,500 lineal feet of timbered tunnel through fairly soft sandstone and shales, at $44.00	154,000
2,300 lineal feet of untimbered tunnel through good sandstone, etc., at $31.50 . .	72,450

(4) A 10-foot diameter tunnel offset to San Antonio, with a gatehouse for regulation of delivery of water from Hetch Hetchy into the reservoir, as well as discharge of water back into the main aqueduct.

500 lineal feet of 10-foot diameter tunnel through sandstone, and some loose ground, all timbered, at $38.00	19,000
Carried forward	$357,950

	Brought forward	$357,950
(5)	One gatehouse, sub-structure 110 feet high, with sluice gates, hoisting equipment, also a moderately expensive superstructure, all complete, including 8,000 cubic yards mixed excavation for gatehouse and waterway	56,000
(6)	San Antonio Dam and Reservoir, earth-fill dam 170 feet high, 900 feet thick at base and 1,800 feet long on crest, built by hydraulic method, including preliminary excavation of unsuitable material at damsite, reinforced concrete core-wall, slope paving, rock-fills at foot of slopes, concrete overflow wier, with sluice gates and concrete lined waste channel, arch bridge over spillway, care of water during construction, roads and residence and stable for keeper, all complete	668,600
	Total construction cost for Calaveras-Antonio Division, including construction of San Antonio dam, all exclusive of cost of general administration, heavy plant and contractor's profit	$1,082,600

IF THE WORK IS PUSHED FORWARD TOWARD THE MOUNTAINS WITHOUT BUILDING THE ANTONIO RESERVOIR THE ABOVE COST WOULD BE LESSENED BY ABOUT $725,000.

Seventh Division, Antonio-Valle

This comprises the additional work necessary to reach the proposed Valle Reservoir of the Spring Valley Water Company and make the supply from the Valle watershed available. Possibly the work may be pushed on toward the Sierras without utilizing the reservoir site. (See map and profile, page 113.) This section extends from the junction of the branch to San Antonio Reservoir at mile 52.75 to mile 59.6; length, 6.85 miles.

(1) Pressure tunnel for the entire length from San Antonio junction to the shaft at mile 59.6, in the bottom of the Valle Creek, or 36,200 lineal feet of 12.8 feet diameter tunnel, lined full length with concrete.

This tunnel will run through the formations of four different geological periods, therefore the excavation to be encountered, though all of sedimentary origin, will be very varied in character.

After going through about 2.3 miles of the generally massive ledges of soft sandstone of the Santa Margarita period, which have been previously mentioned, we may possibly enter the Pliocene gravels, which appear to fill the ancient valley of Indian Creek, although our line has been shifted to the south in order to avoid them. An enormous deposit of these so-called gravels fills the deeper portions of the Livermore and Sunol basins many hundred feet deep, and overlaps thickly onto the foothills and into the narrow valleys and ravines south and southeasterly from Livermore Valley.

These so-called gravels appear to consist mainly of a gritty clayey material, which others than a geologist might classify as adobe. The percentage of coarse sand in it is small, and the pebbles and cobbles are so few as to be scarcely noticeable. This material appears to be quite porous and erodes rapidly wherever water can gather with any force. It has little cohesion and breaks down freely when wet. It is safe to presume that below a certain depth the ground is thoroughly saturated with water, and that below 100 feet in depth water in large quantity would have to be contended with. Therefore the line must be deviated materially from a direct course to wholly avoid these gravels, and in doing so is necessarily thrown back into the hills, thus putting the shaft sites at higher elevations and increasing the depth of the shafts materially. The gravels dip to the northward at an angle varying from 10 to 20 degrees, and overlie older formations which slope in under them. This being the case it is evident that with the tunnel 200 feet and more below the surface it would be possible for it to be in one of the older formations, even though surface indications showed nothing but gravel. How far it may be possible to shorten the line by intruding over the southern limits of the surface indications of these gravels and yet keep the tunnel safely in the better tunneling ground of the older formations cannot be determined with any certainty until after a number of test borings have been made.

It is purposed to avoid tunneling through these gravels, wholly if possible. With this in view the line has been laid as far south into the hills as seems reasonable at this time, with the meagre information available. It is possible that the Pliocene formation between Miles 54 and 56 does not extend as deep as has been indicated on the profile, also the lower and older portions of the gravel showed well-defined thick beds of fine-grained material somewhat indurated and apparently fairly impervious to water. Perhaps on further investigation this lower bed or beds may prove sufficiently good.

From the gravel the tunnel will pass into the Franciscan formation of interbedded shales, schists and sandstones, with some very limited intrusions of serpentine. Some of the beds are good, firm rock, and others are soft or blocky. In the 2½ miles of this Franciscan formation there will be both good and bad ground, but nothing very difficult. Probably from 70 to 80 per cent of this section will require to be timbered.

Near Mile 58 the tunnel will run into the Knoxville and Chico formations.

The Knoxville series is made up of evenly interbedded hard and soft shales and sandstones in layers generally 6 to 18 inches in thickness so far as observed. With the steep dip at which the strata occur, tunneling is not likely to be difficult or dangerous.

The Chico formation, however, is made up of soft and hard sandstone which seems to run very unevenly. At some exposures the rock looks very favorable for tunnel work, and at others it is most uninviting. Probably some very heavy ground will be found in some portions of this formation, and from 70 to 80 per cent of timbering will be required in the two formations taken together.

Some water will be found in this section, especially in some of the Knoxville beds, but not in troublesome quantity.

Three intermediate shaft sites have been indicated. The longest length of tunnel between shafts is about three miles.

The above classification has been estimated to cost as follows:

10,000	lineal feet through Santa Margarita formation, with 60 per cent timbered, at $41.00	$410,000
4,200	lineal feet through wet Pliocene gravels, 100 per cent heavily timbered, heavy section of concrete lining, at $52.50	220,500
11,600	lineal feet through Franciscan formation, with 80 per cent timbered, medium section of concrete lining, at $52.25	606,100
10,380	lineal feet through the Knoxville and Chico formations, 80 per cent timbered, medium section of concrete lining, at $49.00	508,620

(2) Four shafts, severally 40, 230, 200 and 300 feet deep, located at miles 52.8, 54.75, 56.45 and 59.6, respectively. These shafts to be double compartment and will have to be securely timbered for the full depth. It is even possible that the Indian Creek shaft in the Pliocene gravel will have to be concrete lined to exclude the water from the tunnel. The concrete cost will probably be balanced by the cheaper cost of excavation of gravel instead of rock.

Carried forward $1,745,220

Brought forward $1,745,220

These shafts are accessible by good, easy road to within less than one mile of each site. Sunol is the nearest railroad point, giving shaft distances by wagon road of from four to nine miles.

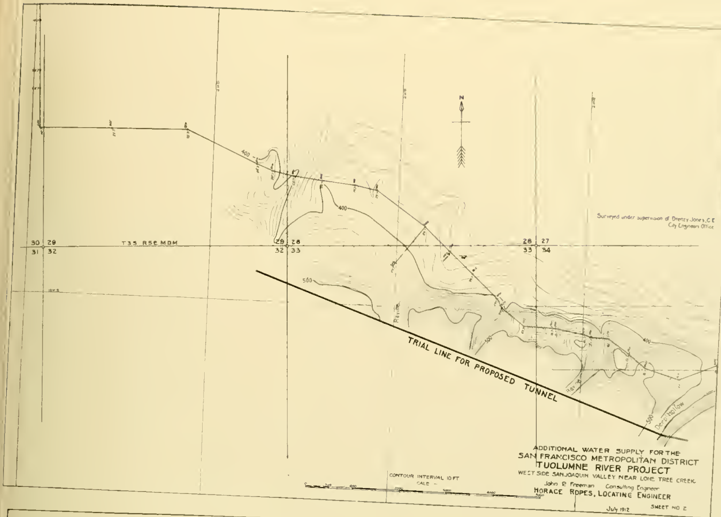
870	lineal feet of double compartment shafts, strongly timbered for full depth, at $125.00	108,800
	Total construction cost, Antonio-Valle Division, exclusive of general administration, heavy plant, and contractor's profit	$1,854,000

Eighth Division, Valle-Moccasin

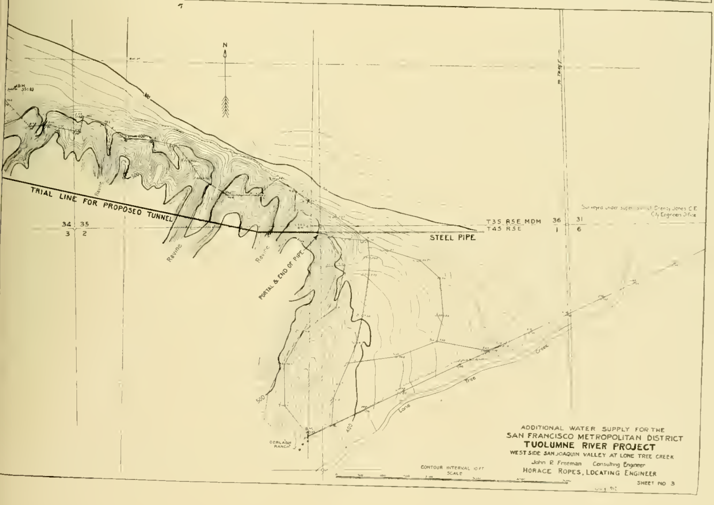
This division forms an extension of the main aqueduct from the Valle Reservoir to Moccasin Creek, where it would be feasible, as a temporary expedient, to pick up some portion of the Tuolumne River flow, to which the city might be entitled, by means of a hillside ditch, or if preferable a wood-stave pipe, which would tap the river near or above the mouth of Rough and Ready Creek, making a branch line six or seven miles in length. The object of this would be to defer the construction of the 19-mile tunnel between Moccasin Creek and Cherry Creek mouth until such time as the needs of the city should exceed the limited supply to be obtained by branch line in the manner stated, or until it should become profitable to utilize the power drop at Moccasin Creek. This might be for ten years or more, and the interest saved on the cost of the long tunnel during that time would greatly exceed the cost of the temporary construction of the branch so that the latter when abandoned would not represent an actual loss of money. Under this treatment one would rely for sanitary safeguard upon the long detention of the water in the great Crystal Springs Reservoir, and for the east side of the bay could earlier undertake the enlargement of Lake Chabot, as described in Mr. Freeman's report.

The works to be built comprise:

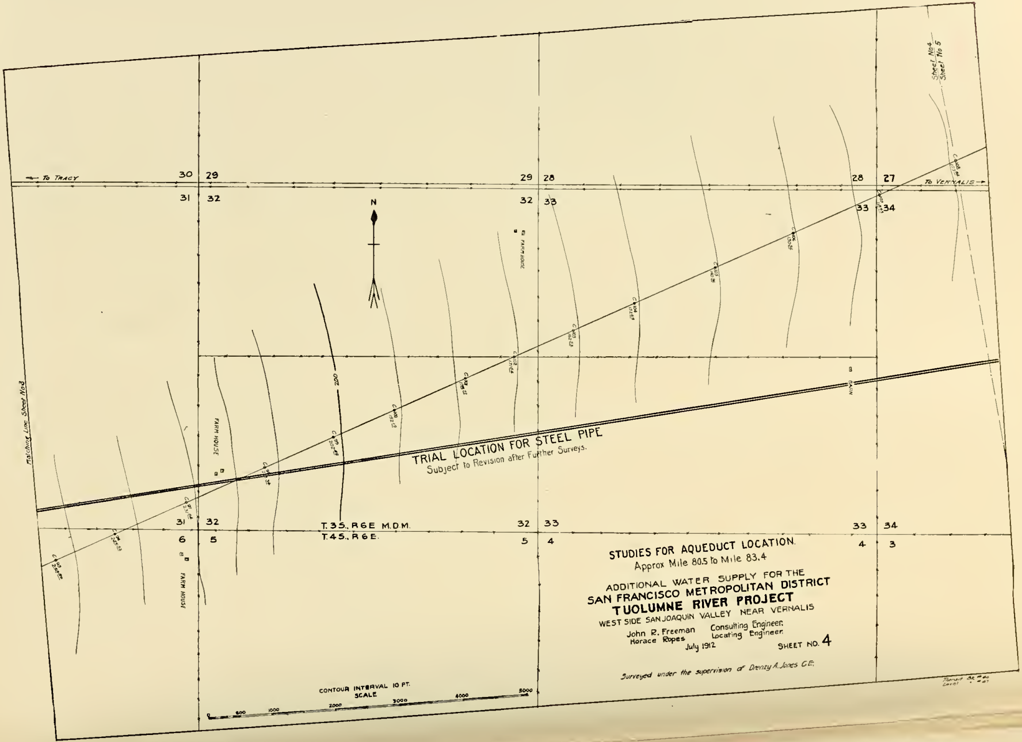
A pressure tunnel, 12.8 feet diameter, from Valle Reservoir to the west edge of the San Joaquin Valley, mile 59.6 to mile 79.1. This will



ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
WEST SIDE SAN JOAQUIN VALLEY NEAR LONE TREE CREEK
John R Freeman Consulting Engineer
HORACE ROPES, LOCATING ENGINEER
July 1912 SHEET NO 2



ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
WEST SIDE SAN JOAQUIN VALLEY AT LONE TREE CREEK
John R Freeman Consulting Engineer
HORACE ROPES, LOCATING ENGINEER
SHEET NO 3
July 1912

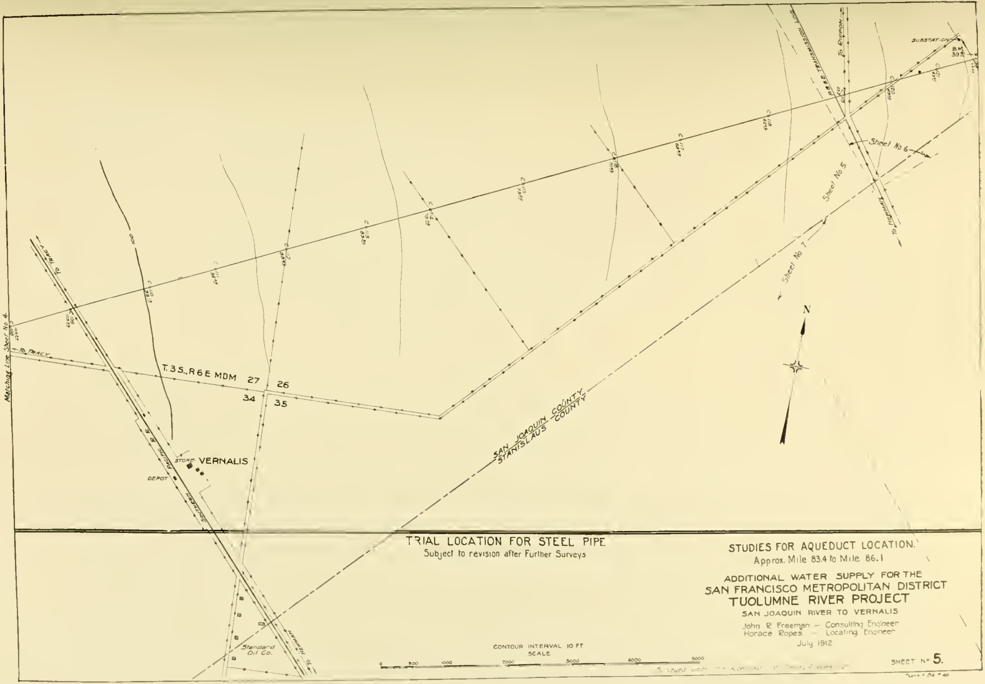


STUDIES FOR AQUEDUCT LOCATION.
Approx Mile 80.5 to Mile 83.4

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
WEST SIDE SAN JOAQUIN VALLEY NEAR VERNALIS

John R. Freeman Consulting Engineer.
Horace Ropes Locating Engineer.
July 1912 SHEET NO. 4

Surveyed under the supervision of Drenzy A. Jones C.E.



TRIAL LOCATION FOR STEEL PIPE
Subject to revision after Further Surveys

STUDIES FOR AQUEDUCT LOCATION.
Approx. Mile 83.4 to Mile 86.1

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
SAN JOAQUIN RIVER TO VERNALIS

John R. Freeman — Consulting Engineer
Horace Ropes — Locating Engineer
July 1912

CONTOUR INTERVAL 10 FT
SCALE

SHEET Nº 5.

include two or three short lengths of steel pipe siphon for which data is uncertain	19.5 miles.
A steel pipe line, 7 feet 6 inches net diameter, and appurtenances, across San Joaquin Valley, mile 79.1 to mile 124.0	44.9 "
A pressure tunnel, 12.8 feet diameter, from the east edge of the San Joaquin Valley to the west bluff of the Tuolumne River, near Red Mountain Bar, mile 124.0 to mile 134.25. This includes a pipe siphon about 600 feet long at mile 125.1	10.25 "
A steel pipe siphon across the canyon of the Tuolumne River, mile 134.25 to mile 134.65	0.4 "
A pressure tunnel, 10 feet diameter, from the west bluff of Tuolumne Canyon to Moccasin Creek, mile 134.65 to mile 140.2	5.55 "
Total length of Eighth Division	80.6 miles.

(1) 102,960 lineal feet of 12.8 feet diameter pressure tunnel, concrete lined for entire length.

This tunnel in its course from the shaft at the Arroyo Valle to its east portal at the edge of the San Joaquin Valley will pass thru five different geological formations in the following order,—Knoxville, Chico, Franciscan, Santa Margarita and Pliocene. The rocks are all of sedimentary nature, except for some very local intrusions of serpentine, which may occur in the Franciscan series.

To merely name the five principal groups of rocks falls far short of giving an adequate description of the variety of ground for tunnelling which this region presents. There are sandstones, shales, schists and clays, inter-bedded in thick and thin layers, in some places fairly massive, in others much jointed and blocky.

The sandstones are usually not very hard and many beds are so soft as not to be able to withstand the weather. Some of the sandstone beds are of good thickness, 6 feet and upward, but in general the stratification of the sandstone as also of the shales, is in thin beds of one foot or less in thickness, with layers of rather hard rock inter-bedded with much material of a softer, disintegrating character. Especially is this so of the shales, where many of the beds appear to be scarcely more than a hard clay, which slacks and crumbles on exposure to the air. The strata of these formations have greatly varying dips at different places. Where the dip is great and the strike is nearly at right angles to the course of the tunnel, it is much more favorable for excavating than where the dip approaches the horizontal or the strike of the rock nearly parallels the direction of the tunnel. The surface exposures of the underlying rocks are so few thruout this region that it was impossible to form any definite opinion as to how much of the tunnelling would be thru hard or soft rock and what distance would be in good ground requiring little or no timbering, or how much would present greater difficulties. There is no way of determining these points with any degree of certainty in advance of the actual excavation of the tunnel, except by a thoro geological study of the region along the line, which, together with the information derived from necessary borings and test pits, will make it possible to show the geologic section on the tunnel line within reasonable enough limits of accuracy to predict the character of the work.

It was discovered that Corral Hollow, about one mile north and approximately parallel to the present tunnel location, marks the line of a great fault which has caused widespread disturbance of the adjacent rocks, so much so as to make it wholly inadvisable to attempt to decrease the depth of shaft work by making the tunnel location near the lower levels of that valley. Whether pushing the tunnel location about one mile southerly from Corral Hollow has moved it safely outside of the region of fault disturbance can only be determined by borings and the expert geological investigation previously mentioned.

For a continuous stretch of more than 10 miles the tunnel will probably be in the Franciscan series, a diverse formation which seems to contain all varieties of sedimentary rocks from conglomerate and coarse sandstone, thru shaley sandstones and shales even to some kind of limestone. However, so far as I could judge, a moderately fine-grained sandstone, fairly uniform in character and in beds of considerable thickness, seems to predominate. The great depth at which the tunnel lies in this wide, unbroken belt of the one formation, for the greater part of the way more than one-quarter of a mile below the surface, warrants the expectation that a considerable proportion of the ground to be tunnelled thru will be self-supporting. It seems conservatively safe, therefore, to estimate for only 80 per cent of tunnel length, as of the timbered type of section. In the other formations the same percentages of length to be timbered have been used as heretofore, viz:

Knoxville and Chico formations, 80 per cent timbered.

Santa Margarita formations, 60 per cent timbered.

Pliocene gravels, 100 per cent timbered.

Pliocene gravels overlying the tunnel location between Miles 60 to 62, and for a quarter of a mile near Mile 72, can be seen on the surface. Altho the depth of the gravel at these places has not yet been tested and is therefore unknown, it appears probable, from the lay of the rocks in the adjoining hills, that the gravel does not reach down so deep, but that the tunnel will avoid them by keeping in the older underlying rocks.

It is expected that nearly four miles of the east portion of the tunnel will be thru Pliocene gravels, which in a layer of great thickness overlap the lower slopes of the mountains and form a terrace along the westerly side of the San Joaquin Valley. It is possible to eliminate most of this gravel work by making a detour and running up one of the deep cut ravines, such as Deep Hollow. To do so, however, would make a bad crook in the line, increasing the distance materially and obligating the use of more steel pipe. This alternative deserves much more study than has yet been given it, but for the present the tunnel has been assumed to be the better plan.

Tunnelling in the gravel at this place should be a very different proposition from that in the region south of the Livermore Valley. Here the tunnel grade is high above the general surface of the San Joaquin Valley and also parallels the bluffs of the terrace at only a short distance back from their steep face and because of these favorable conditions the gravel through which the tunnel will pass is probably well drained and fairly dry. Also the tunnel is at shallow depth below the surface, giving a comparatively light weight of over-burden to be supported. On the other hand, south of Livermore the tunnel grade is far below the surface where the gravels are saturated with water, rendering the work difficult and costly, and therefore requiring more or less of a detour in order to avoid them.

A moderate amount of water may be looked for in the form of seepage and small drippings at places thruout the length of this tunnel, but in the aggregate not enough to require more than the ordinary pumping usually necessary in tunnels driven from shafts.

The above described 102,960 lineal feet of tunnel work has been classified and estimated to cost as follows:

8,710 lineal feet through Knoxville and Chico formations, with 80 per cent timbered, at $48.00	$418,100
55,970 lineal feet through Franciscan formation, with 80 per cent timbered, at $53.50	2,994,200
18,210 lineal feet through Santa Margarita formation, with 60 per cent timbered, at $42.00	764,800
Carried forward	$4,177,100

Brought forward	$4,177,100
20,070 lineal feet through Pliocene gravel, 100 per cent timbered, little water, at $40.50	812,800

(2) Eight double-compartment shafts, severally 490, 680, 700, 670, 290, 60, 80 and 100 feet deep, located at Miles 61.3, 62.8, 66., 68.2, 71.8, 75.7, 76.25, and 77 respectively. All will require to be timbered and the one thru the Pliocene gravel on Mile 62, also the one on Mile 71, will need to be lined with concrete for a part of their depth, to prevent free entrance of water thru the shaft to the tunnel workings. It is assumed that the cheaper cost of excavation in gravel will compensate for the greater cost of shaft lining.

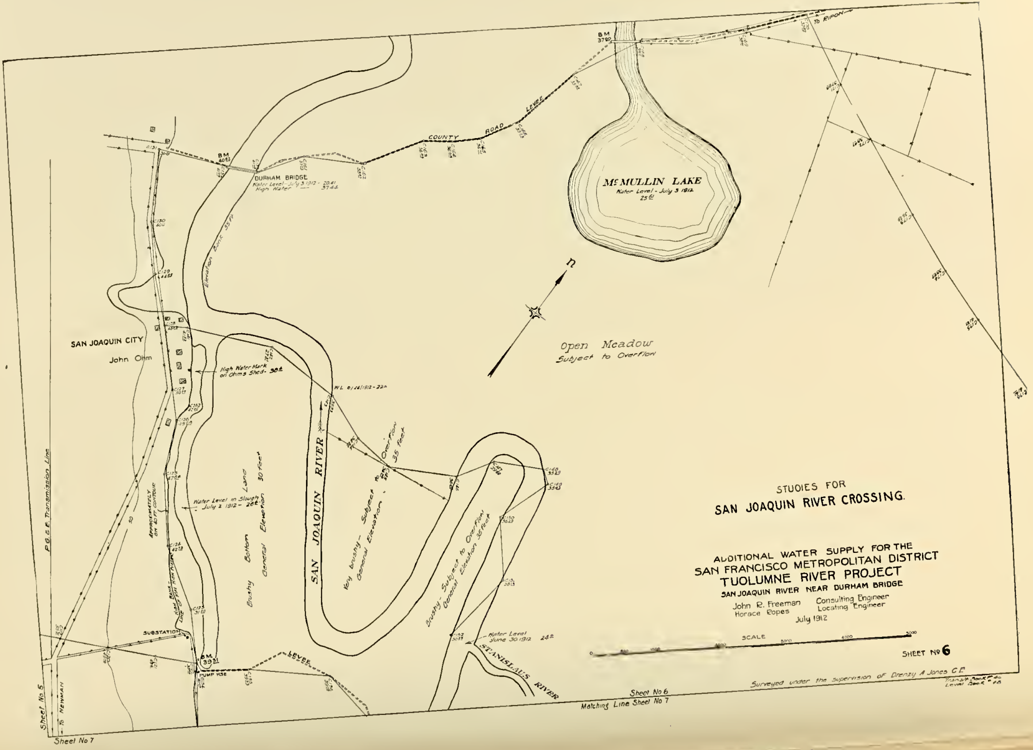
The two western shafts are 11 or 12 miles distant from Livermore, their railroad base of supplies. Good roads approach to within two miles of each site, but from there trails would have to be improved or new roads built. In the immediate vicinity of the sites the ravines are narrow and rough and the hills very steep.

The six remaining shafts are near the branch line of the Western Pacific Railroad to Tesla. They are located in ravines back in the hills at a considerable elevation above the railroad so that about six miles of road would have to be improved or newly constructed to make hauling easy.

Because of the much greater depth of four of the shafts than of those previously estimated, also the possibility of difficulties and delays due to keeping them free from water, and to allow for the extra road work necessary, a higher average price is here used.

In addition to the shafts mentioned it is proposed to provide a surge tank in the shape of a shaft about 110 feet deep with suitable spillway at the east end of the tunnel, Mile 79.1. This has been included with the other shafts and at the same price per foot. After more study it may be found preferable to substitute for this shaft a small equalizing basin with less depth of shaft in the ravine at about Mile 78.9.

Carried forward	$4,989,900



STUDIES FOR

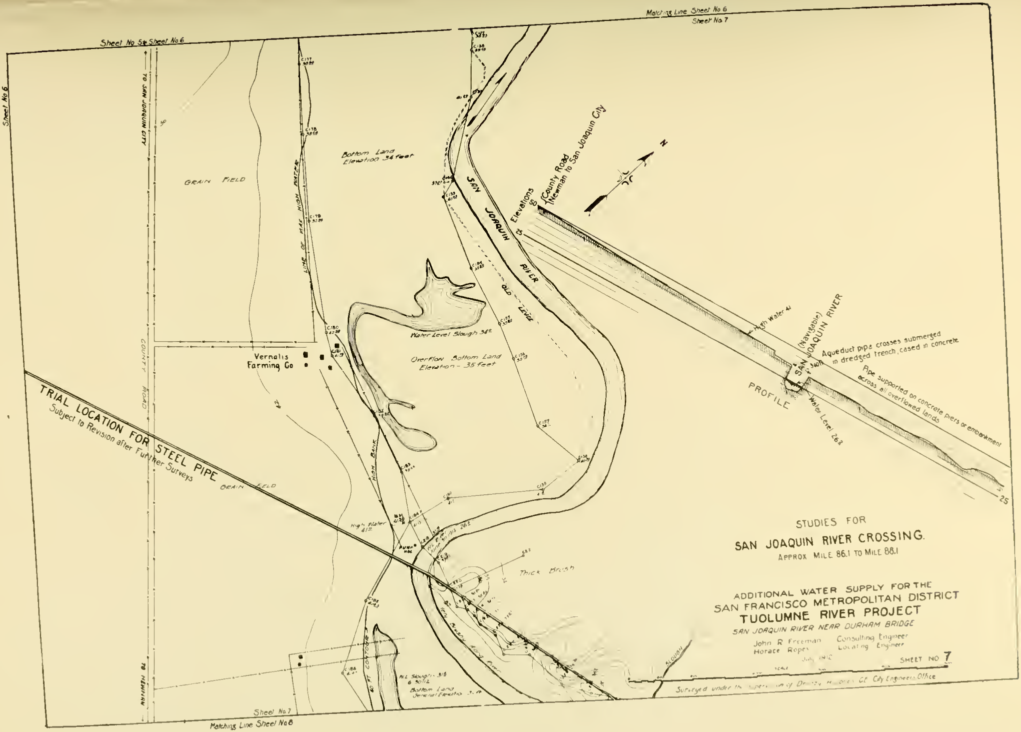
SAN JOAQUIN RIVER CROSSING.

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
SAN JOAQUIN RIVER NEAR DURHAM BRIDGE

John R. Freeman Consulting Engineer
Horace Ropes Locating Engineer
July 1912

SHEET No 6

Surveyed under the supervision of Drenzy A Jones C.E.



STUDIES FOR

SAN JOAQUIN RIVER CROSSING.

APPROX MILE 86.1 TO MILE 88.1

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
SAN JOAQUIN RIVER NEAR DURHAM BRIDGE

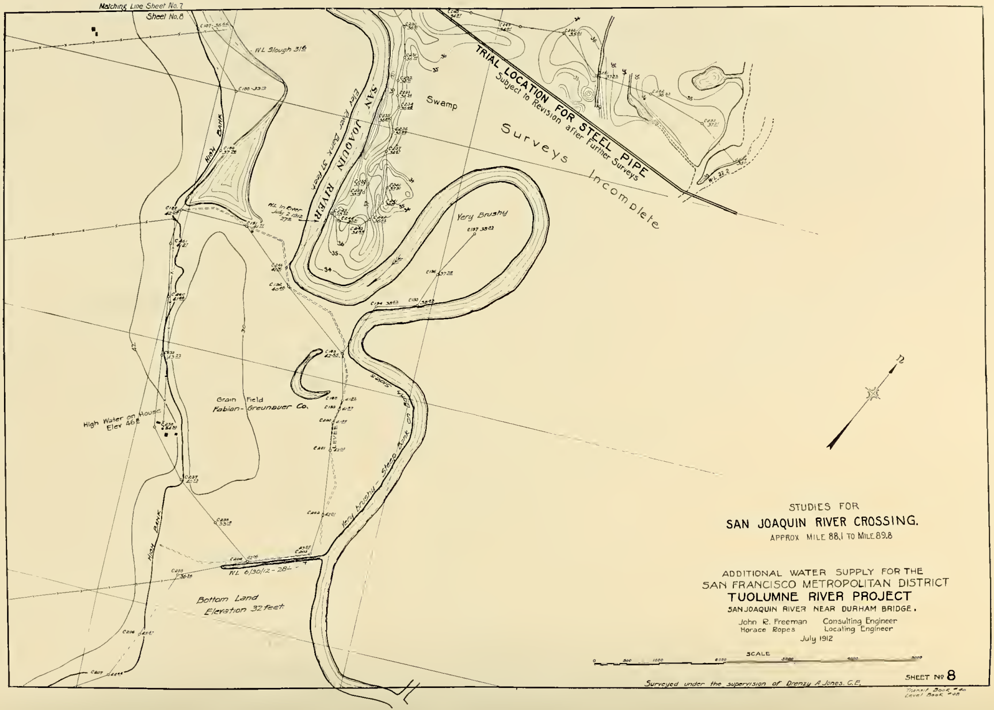
John R Freeman Consulting Engineer
Horace Ropes Locating Engineer

July 1912

SHEET NO 7

Surveyed under the supervision of Dr[illegible] [illegible] C.E. City Engineer's Office

Matching Line Sheet No 6
Sheet No 7
Sheet No 5 & Sheet No 6
Sheet No 6
TO SAN JOAQUIN CITY
COUNTY ROAD
TO NEWMAN
GRAIN FIELD
Bottom Land Elevation 34 feet
LINE OF MAX HIGH WATER
Vernalis Farming Co
Water Level Slough 34.2
Overflow Bottom Land Elevation - 35 feet
SAN JOAQUIN RIVER
OLD LEVEE
HIGH BANK
High Water 41.2
Thick Brush
Slough
40 FT CONTOUR
Bottom Land General Elevation 31
TRIAL LOCATION FOR STEEL PIPE
Subject to Revision after Further Surveys
GRAIN FIELD
Sheet No 7
Matching Line Sheet No 8
N
Elevations 50 25
County Road Newman to San Joaquin City
High Water 41
(Navigable) SAN JOAQUIN RIVER
Aqueduct pipe crosses submerged in dredged trench, cased in concrete
Pipe supported on concrete piers or embankment across all overflowed lands
Water Level 26.2
PROFILE
25


Matching Line Sheet No. 7
Sheet No. 8
W.L. Slough 31.6
High Bank
SAN JOAQUIN RIVER
Elev River Bank 37 feet
W.L. in River July 2 1912 27.8
Swamp
TRIAL LOCATION FOR STEEL PIPE
Subject to Revision after Further Surveys
Surveys Incomplete
W.L. 32.2
Very Brushy
Steep Bank on Outside
Very brushy - Steep Bank on Outside
LEVEE
Grain Field
Fabian-Greunauer Co.
High Water on House Elev 46.8
W.L. 6/30/12 - 28.4
Bottom Land
Elevation 32 feet
High Bank
N
STUDIES FOR
SAN JOAQUIN RIVER CROSSING.
APPROX MILE 88.1 TO MILE 89.8
ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
SAN JOAQUIN RIVER NEAR DURHAM BRIDGE.
John R. Freeman Consulting Engineer
Horace Ropes Locating Engineer
July 1912
SCALE
0 500 1000 2000 3000 4000 5000
SHEET No 8
Surveyed under the supervision of Drenzy A Jones. C.E.
Transit Book #40
Level Book #28

Brought forward $4,989,900

3,180	lineal feet double compartment shafts, strongly timbered for full depth, and in part lined with concrete, at $125.00	$397,500

(3) Open cut and pipe connections at the east portal of the Tesla Tunnel.

9,000	cubic yards compact gravel excavation, at 35 cents	3,200
380	lineal feet tunnel excavation, enlarged special section to admit two 7.75-foot steel pipes, at $30.00 . .	11,400
260	cubic yards concrete refill around pipes in tunnel, at $7.25	1,900

(4) 237,240 lineal feet of steel pipe siphon 7.75 feet diameter, across San Joaquin Valley. The working diameter of this pipe will be reduced to 7.5 feet net by the interior cement lining 1½ inches thick.

For nine-tenths of its length the pipe will be laid over the level and dry plain which forms the floor of the valley. On this portion it is proposed to bury the pipe, putting it about two-thirds under ground, and covering the remaining portion by a low embankment made by replacing the previously excavated material from the trench. For the shallow trenching required, the excavation will consist mainly of the surface soils, though in places it will penetrate the hardpan to some extent, particularly for the easterly eight or ten miles where hardpan in the form of "tuff" is reached within two or three feet of the surface. This "tuff" resembles a soft very fine-grained sandstone. It is somewhat harder than the surface material but will not be much more expensive to excavate with a steam shovel.

At the crossing of the San Joaquin River, which it is proposed to make about 3,200 feet southeasterly from the Vernalis Farming Company's buildings, thus keeping safely upstream from the confluence of the Stanislaus River, we find the river has two channels. The larger and main channel from 300 to 400 feet wide, and a back channel or slough about 200 feet wide.

Carried forward $5,403,900

Brought forward $5,403,900

These channels are separated at this place by low bottom land about 1.6 mile wide. This bottom land has a general level of seven to eleven feet above ordinary June stage of the river, but is generally submerged during freshets which at the very highest stage will reach a depth of eight to ten feet over the lower portions of the bottoms.

It is proposed to submerge the pipe across the main channel, bridge the back channel and to carry the pipe over the bottom lands partly on an embankment of earth and partly on a trestle of heavy concrete piles and cross beams. The bottom of the pipe at the waterways under the bridge and trestle to be not less than five feet above the level of the highest freshet, to allow ample room for the passage of drift wood, etc.

The material in the bottoms is a sandy silt overlying a stratum of hard clayey hardpan to a depth of from 10 to perhaps 20 feet. There are no soft, mucky places and the ground is capable of bearing the load due to the embankment and water-filled pipe without danger of any serious settlement. Neither is there any danger to be apprehended from washouts, if the bank is compactly built, and the slopes properly protected.

In addition to the surge tank at the west end, the blow-off at the river, and manholes and expansion joints at suitable intervals, a surge tank or as further investigation may show to be better, a small equalizing reservoir will be provided at the east end of the pipe. Shut-off gates will also be located at the east end of the pipe.

This 237,360-foot length of 7.75 ft. diameter steel pipe, and its appurtenant structures have been classified and estimated as follows:

6,460	lin. ft. 1/4-inch shell (maximum head 140 feet) @ $13.00 . . . . .$	84,000
18,480	lin. ft. 3/8-inch shell (average head 240 feet) @ $16.50	304,900

Carried forward $5,792,800

Brought forward	$5,792,800
24,290 lin. ft. 9/16-inch shell (average head 370 feet) @ $22.00.	534,400
24,290 lin. ft. 5/8-inch shell (average head 400 ft.) @ $23.00.	558,700
10,560 lin. ft. 11/16-inch shell (average head 435 feet) @ $25.00.	264,000
59,400 lin. ft. 3/4-inch shell (average head 485 feet) @ $26.50.	1,574,100
93,450 lin. ft. 13/16-inch shell (average head 510 feet) @ $28.00.	2,616,600
430 lin. ft. 7/8-inch shell (average head 540 feet) @ $30.00.	12,900

The prices used above accord with Mr. Freeman's analysis of the cost of steel pipe for the San Joaquin Valley siphon. (See Appendix 8, page 235.)

To the above there should be added to obtain the final total cost, an allowance for administration, contractor's profit and miscellaneous, all as previously specified on page 240, as omitted. The charge for cost of equipment after salvage value has been deducted is in this case included in unit prices for pipe as computed by Mr. Freeman.

The following additions must also be made for the extra cost of placing the pipe on embankment, for special work at river crossings and for minor structures.

The total distance across bottoms subject to overflow by extreme floods is about 3 miles. To keep the pipe well above high water and at the same time maintain an even grade across the bottoms will require nearly 5 miles of embankment and bridging.

17,000 lin. ft, embankment on dry land, average height 12.5 feet, or 180,000 cu. yds. scraper work, @ 18c	$32,400
6,230 lin. ft. embankment on overflowed bottoms, average height 19 ft., built by dredging from downstream side only; some clayey hardpan to handle, 156,000 cu. yds, @ 15c	23,400
Rip-rapping exposed slopes	1,800
Carried forward	$11,411,100
Brought forward	$11,411,100

For 2,640 lin. ft. of trestle across overflowed bottoms, 60-foot spans of self-supported pipe on piers of concrete piles of large diameter, allow as follows:

2,640 lin. ft. pipe with 1/16-inch extra thickness of shell . . . . @ $2.40	6,300
For 43 piers, average height 20 feet, with piles set 20 feet in ground.	
86 piles, 3 feet diameter, in place, @ $150	12,900
172 piles, 2 feet diameter, in place, @ $85	14,620
Concrete caps, bracing, etc., for 43 piers, @ $210	9,600

For 320 lin. ft. of submerged pipe at main channel crossing, allow as follows:

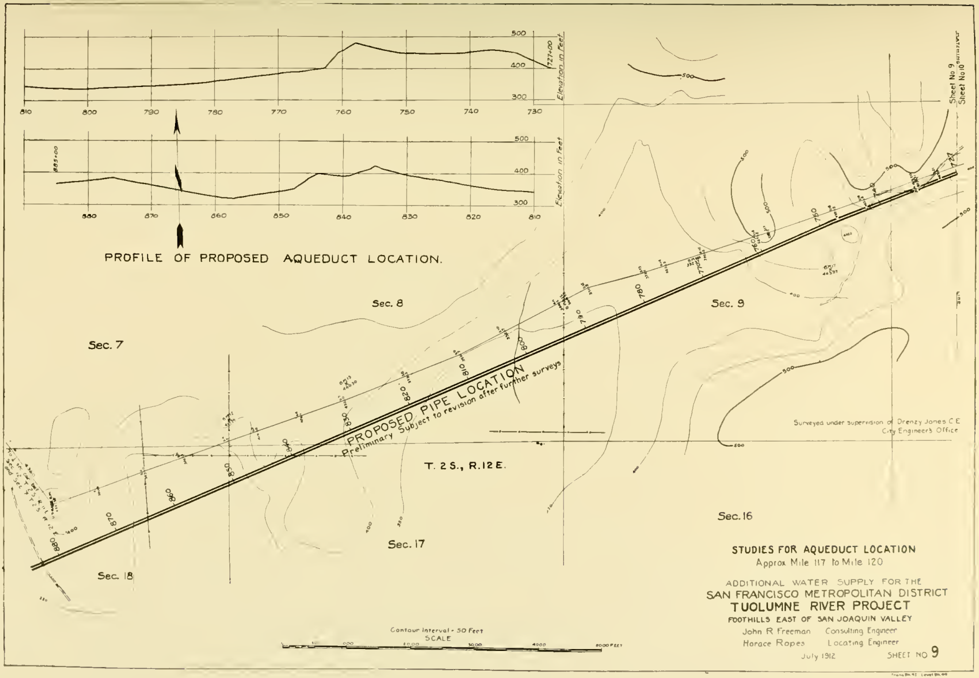
320 lin. ft. of trench 15 feet deep, dredged across main channel, probably all stiff clayey material, with extra work for disposal. 44,000 cu. yds., @ 30c.	13,200
350 cu. yds. concrete casing built above water, @ $7.00	2,500
1,100 cu. yds. concrete casing laid under water, @ $14	15,400
Cofferdam built in 6 successive sections about 50 feet long, at $14,000 each . . .	84,000

For bridge over back channel 200 feet wide, assume two spans of self-supported pipe on one central pier and two concrete abutments.

Cofferdams and excavation	18,000
580 cu. yds. concrete . . . . @ $9.00	5,200
300 lin. ft. of pipe with ⅛-inch extra thickness of shell. . . . . @ $4.60	1,400
False work for erecting pumping, miscellaneous	5,000
Estimated cost of gate house at main river crossing to contain bailing apparatus for submerged siphon, and the blow-off valves; also for 44 man-holes, expansion joints, etc.	21,000
Allowance for 88 miles of fencing at $200 per mile, for six railroad crossings, 22 highway crossings; main and lateral irrigation ditches and other waterways	65,600

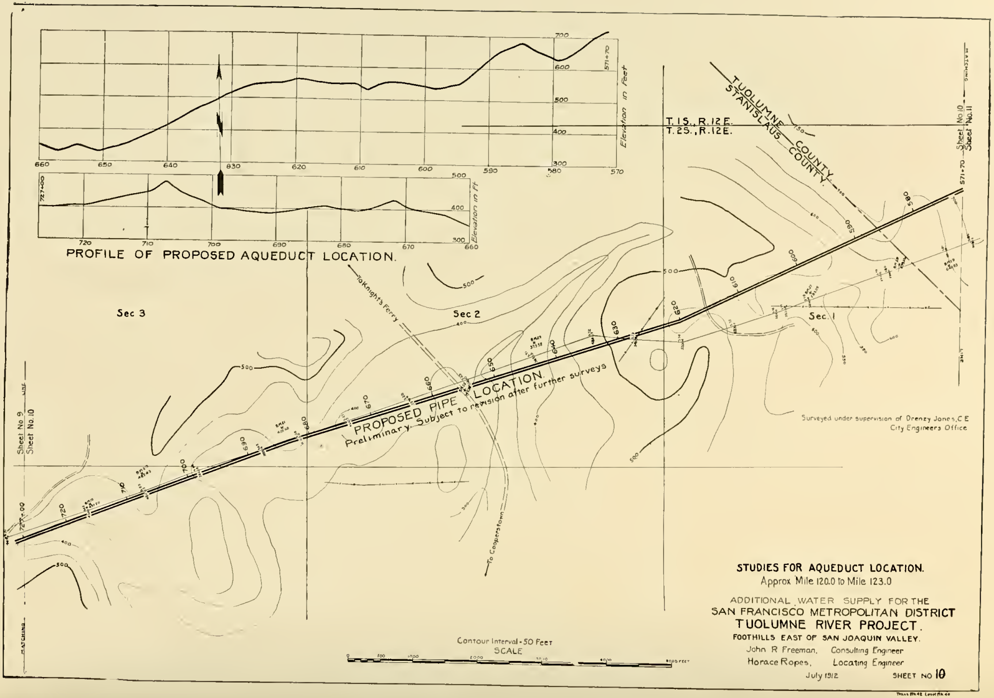
(5) Portal cut and pipe connections at the west end of Dry Creek Tunnel.

2,800 cu. yds. earth excavation . . . @ 30c	$ 800
8,500 cu. yds. rock excavation . . @ $1.00	8,500
Carried forward	$11,695,100



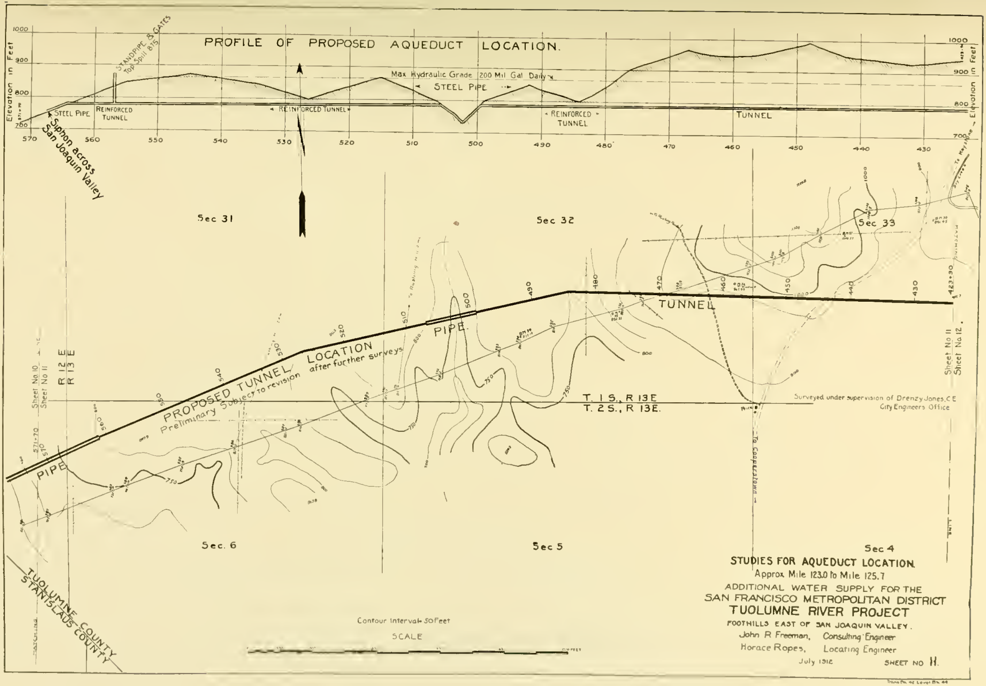
STUDIES FOR AQUEDUCT LOCATION
Approx Mile 117 to Mile 120

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
FOOTHILLS EAST OF SAN JOAQUIN VALLEY
John R Freeman Consulting Engineer
Horace Ropes Locating Engineer
July 1912 SHEET NO 9

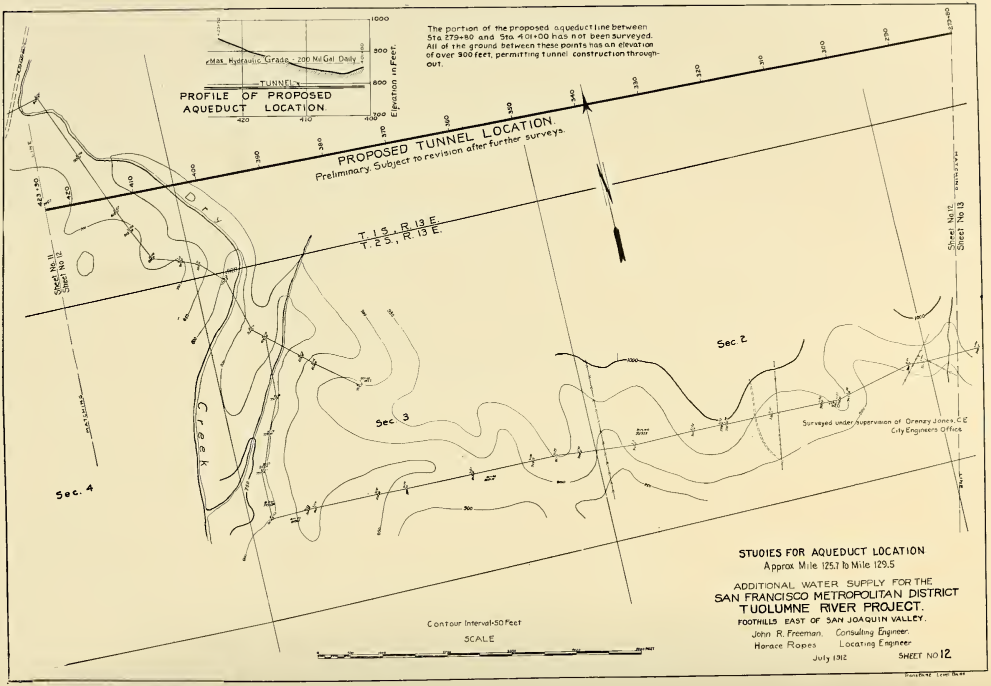


STUDIES FOR AQUEDUCT LOCATION.
Approx Mile 120.0 to Mile 123.0

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT.
FOOTHILLS EAST OF SAN JOAQUIN VALLEY.
John R Freeman, Consulting Engineer
Horace Ropes, Locating Engineer
July 1912
SHEET NO 10



STUDIES FOR AQUEDUCT LOCATION.
Approx Mile 123.0 to Mile 125.7
ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
FOOTHILLS EAST OF SAN JOAQUIN VALLEY.
John R Freeman, Consulting Engineer
Horace Ropes, Locating Engineer
July 1912
SHEET NO 11.

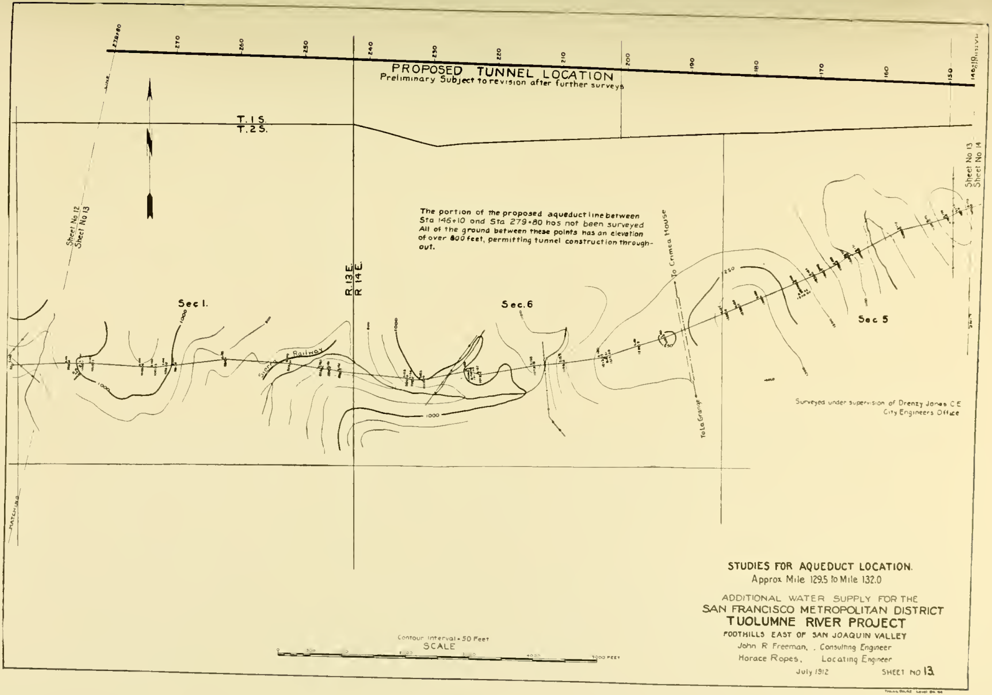


The portion of the proposed aqueduct line between Sta 279+80 and Sta 401+00 has not been surveyed. All of the ground between these points has an elevation of over 900 feet, permitting tunnel construction throughout.

Surveyed under supervision of Orenzy Jones, C.E.
City Engineers Office

STUDIES FOR AQUEDUCT LOCATION
Approx Mile 125.7 to Mile 129.5

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT.
FOOTHILLS EAST OF SAN JOAQUIN VALLEY.
John R. Freeman, Consulting Engineer.
Horace Ropes Locating Engineer
July 1912 SHEET NO 12



The portion of the proposed aqueduct line between Sta 146+10 and Sta 279+80 has not been surveyed. All of the ground between these points has an elevation of over 800 feet, permitting tunnel construction throughout.

Surveyed under supervision of Drenzy Jones C.E.
City Engineers Office

STUDIES FOR AQUEDUCT LOCATION.
Approx Mile 129.5 to Mile 132.0

ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
FOOTHILLS EAST OF SAN JOAQUIN VALLEY
John R Freeman, Consulting Engineer
Horace Ropes, Locating Engineer
July 1912 SHEET NO 13

Brought forward	$11,695,100
600 lin. ft. of pipe tunnel, 22 ft. x 10 ft., 20% timbered . . . . @ $42.00	25,200
220 cu. yds. concrete refill. . . . . @ $7.50	1,600

(6) Surge pipe and gates at the east end of the San Joaquin siphon. The elevation of bottom of tunnel is assumed as 785. The maximum head at this point will occur when only one pipe is in service with hydraulic grade at about elevation 865. The standpipe, 10 feet diameter, with spill at elevation 877 is provided for. Also suitable shut-off gates for the pipe line are provided for as follows:

100 lin. ft. 10-foot diameter pipe, including overflow, also gate house containing shut-off gates to San Joaquin siphon	$21,000

(7) Dry Creek tunnel extending eastward from the end of the San Joaquin Valley pipe line to the west bluff of the Tuolumne Canyon, Mile 124 to 134.25 enters a class of rocks entirely different from those observed on the more westerly portion of the aqueduct line. The formations are harder, and the bedding appears to be less disturbed. The porphyrite, or altered lava, of which there will probably be nearly nine miles in length, as shown on the profile (see Plans D and E), is a hard schistose rock of a crystalline character, spoken of locally as greenstone. The bedding planes of this rock have assumed a nearly vertical position, and outcrops of points and thin slabs which have resisted erosion are to be seen standing out of the ground in almost every direction, giving the country a curious appearance, in many places reminding one of an old country graveyard with its tilted and dilapidated gray headstones. I was fortunate to have a chance to observe the character of this rock underground, in the tunnel now being driven near Knights Ferry, by the South San Joaquin Irrigation District. The rock is hard, and as regards drilling and blasting is comparable to diorite. The vertical cleavage planes are tight and dry. The rock is not otherwise badly jointed and ought not to give much over-breakage outside of the required tunnel section.

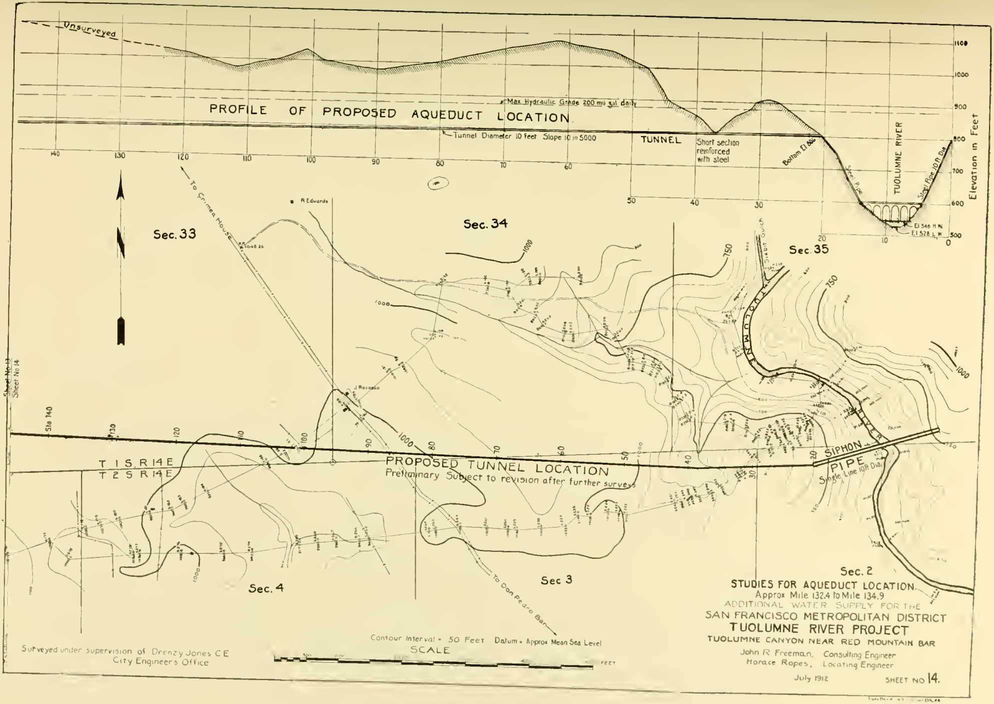
Carried forward	$11,742,900

Brought forward	$11,742,900

At the working point observed the formation was so hard and seamless that the tunnel was perfectly safe without timbering. Surface indications point to uniform conditions all the way through this formation. Possibly a few narrow seams of disintegrated material which may require timbering will be found now and then. To allow for such contingencies 10 per cent of the length is estimated as being of the timbered type.

After the porphyrite, the Mariposa Slate is the next formation of importance to be gone through. These slates, like the porphyrite, have nearly vertical bedding, and would be excellent for tunneling through were it not for the bad cross-jointing of the beds which is their most marked and distinguishing characteristic. In locations where this formation is wet enough to yield water, the tunneling will certainly be troublesome because of heavy falling ground which will have to be carefully worked and well timbered. Where the formation is not wet and the main joints are nearly vertical it is possible that the tunneling will be quite good, but at best it is probably treacherous ground to drive other than small drifts through without considerable timbering. An exposure of these rocks was observed in the vicinity of Jacksonville, and gave me a most unfavorable impression, but they seemed to me to be much better where observed in the vicinity of their occurrence on the tunnel line between Miles 132 and 134. It is my opinion that in the latter locality the formation does not contain much water, and the jointing is sufficiently tight to make the rock self-sustaining for considerable portions of the tunnel for some months or at least until such time as it will be convenient to do the concrete lining. Fortunately only about a mile and a half of the Mariposa formation will be found in this tunnel, and as already intimated it probably can be passed through without much trouble

Carried forward	$11,742,900



STUDIES FOR AQUEDUCT LOCATION.
Approx Mile 132.4 to Mile 134.9
ADDITIONAL WATER SUPPLY FOR THE
SAN FRANCISCO METROPOLITAN DISTRICT
TUOLUMNE RIVER PROJECT
TUOLUMNE CANYON NEAR RED MOUNTAIN BAR

John R Freeman. Consulting Engineer
Horace Ropes. Locating Engineer

July 1912 SHEET NO 14.

Surveyed under supervision of Drenzy Jones C E
City Engineers Office

Contour Interval • 50 Feet Datum • Approx Mean Sea Level

Brought forward $11,742,900

and without being fully timbered. For the purpose of this estimate only 80 per cent of the length is regarded as timbered.

The short stretch of amphibolite at the east end is a firm self-supporting rock which can be gone through without difficulty of any sort.

The tunnel excavation can be attacked at four portals and six shafts. Only two of the latter need exceed 50 feet in depth. The longest distance between shafts as now located will be 5.5 miles. This can be divided into shorter lengths by sinking one or more shafts approximating 300 feet in depth.

This work is all within a four or five-mile haul from the Sierra Railroad, and quite accessible over existing roads, which would require very little improvement, hence cost of transportation for plant and materials will be about the same as for work in the Coast Range.

The estimate for this tunnel is based on the revised location shown on survey plans Nos. 11 to 14 inclusive, instead of the earlier paper location indicated on Plans D and E.

Near Mile 125 the continuity of the tunnel is broken by a branch of Dry Creek requiring about 1,500 feet of steel pipe to cross and to make the necessary overlap into the tunnel. The following classification and cost prices have been adopted:

37,750 lin. ft. through porphyrite, with 10 per cent timbered, @ $42.50	$1,604,400
8,000 lin. ft. through Mariposa slates, with 80 per cent timbered, @ $48.50	388,000
7,200 lin. ft. through Amphibolite, with 10 per cent timbered, @ $41.00	295,200

(8) For short siphon near Mile 125, we have:

1,000 lin. ft. 7.75-foot pipe, ¼-inch shell, @ $14	$14,000
5,600 cu. yds. earth excavation, @ 30c . .	1,700
17,000 cu. yds. rock excavation, @ $1.00	17,000
500 lin. ft. pipe tunnel, @ $42.00	21,000

Carried forward $14,084,200

Brought forward $14,084,200

450 cu. yds. concrete refill, @ $7.50	3,400
Creek crossing	1,800

(9) *Shafts.* The shaft sites have not been indicated on the map or profile but the depth of cover over this tunnel is in general so moderate, it is certain that the tunnel work could be attacked at several places, few or more as the desire for speed may dictate. It will be reasonably close to estimate for at least six shafts, or 550 lineal feet double compartment shafts, at $100.00 55,000

(10) 2,300 lineal feet of steel pipe siphon, 10 feet diameter across the Tuolumne Canyon, including extra length for dip of pipe. The working diameter of this pipe will be reduced to 9.75 feet by a Portland cement lining 1½ inches thick on the inside.

The crossing is at a place where the slopes rise directly and steeply from the river banks. It is about as narrow a place as can be found in the valley thereabouts, but it is somewhat out of a direct course, and future study may show that it would be more economical to gain, at the expense of a longer pipe crossing, the saving in length of tunnel excavation and in other items resulting from a straighter and shorter line.

Ample waterway for the highest freshets occurring at this crossing of the Tuolumne River can be provided for by a bridge 500 feet long with the bottom of the pipe at elevation 560, but to avoid the possibility of this permanent structure becoming in the future an obstacle to the building of a dam at some point downstream, where it would result in raising the water levels at the bridge, the bottom of the pipe is assumed to be at elevation 600 and the bridge is correspondingly lengthened to about 900 feet.

It is proposed to let the pipe form its own bridge, simply by putting a little more metal into the shell, thus making it strong enough to span without further support between masonry piers 80 to 100 feet apart over the main channel. This, however, is a matter

Carried forward $14,144,400

Brought forward $14,144,400

for future study, and for the present a sufficient allowance has been made to fully cover the cost of either a steel or concrete bridge of ordinary design with spans of 100 feet.

The bottom of the canyon is rather a rough place to reach by wagon road, but it is possible to locate a cheap road with good, easy grades to the west end of the pipe, and from there heavy material could be readily handled by a cableway or cable incline.

For this case, the cost price per lineal foot of pipe has been increased over the prices previously used in this estimate by more than the proportionate difference due to the larger size of this pipe because of rock excavation to be done in the steep slopes, the greater difficulty of handling so large a pipe in this rough canyon, and the comparatively short length of pipe to be built, which latter would increase the proportionate plant charges.

This 2,300-foot length of 10-foot diameter steel pipe and appurtenant structures has been estimated to cost as follows:

1,300	lineal feet 7/16-inch pipe (average head, with one San Joaquin pipe in service, 170 feet), at $26.40	34,300
1,000	lineal feet 11/16-inch pipe (average head, with one San Joaquin pipe in service, 270 feet), at $39.60	39,600
900	lineal feet concrete arch bridge across Tuolumne River	47,000
For portal cuts at ends of pipe, allow—		
600	cubic yards earth excavation, at 30 cents	200
5,400	cubic yards rock excavation, at $1.00	5,400
One gate chamber at the east end of pipe line, provided with ordinary sluice gates, also a low surge tank at west end of pipe line, and a blow-off valve at the low point over the river		11,500

Carried forward $14,282,400

Brought forward $14,282,400

(11) 29,300 lineal feet of 10-foot diameter pressure tunnel, concrete lined for entire length. This tunnel, judging by surface outcrops, is regarded as about half and half in amphibolite and porphyrite heretofore described. For a short stretch (probably not more than a quarter of a mile), near the middle of the tunnel, serpentine rock will be encountered.

Serpentine usually occurs as a hard but much fractured rock, being intersected by innumerable fine cracks. The joint planes are inclined to be smooth and to have the slippery feeling of soapstone. This formation also appears to contain more water than usual in rocks of eruptive origin. The rock will be troublesome to drill because of its hardness and the prevalence of the irregular jointing planes. In Professor J. C. Branner's opinion serpentine is one of the very worst of the hard rock formations through which to tunnel, and therefore an effort has been made to steer clear of it as much as possible. It has been assumed that 60 per cent of this portion of the tunnel must be fully timbered.

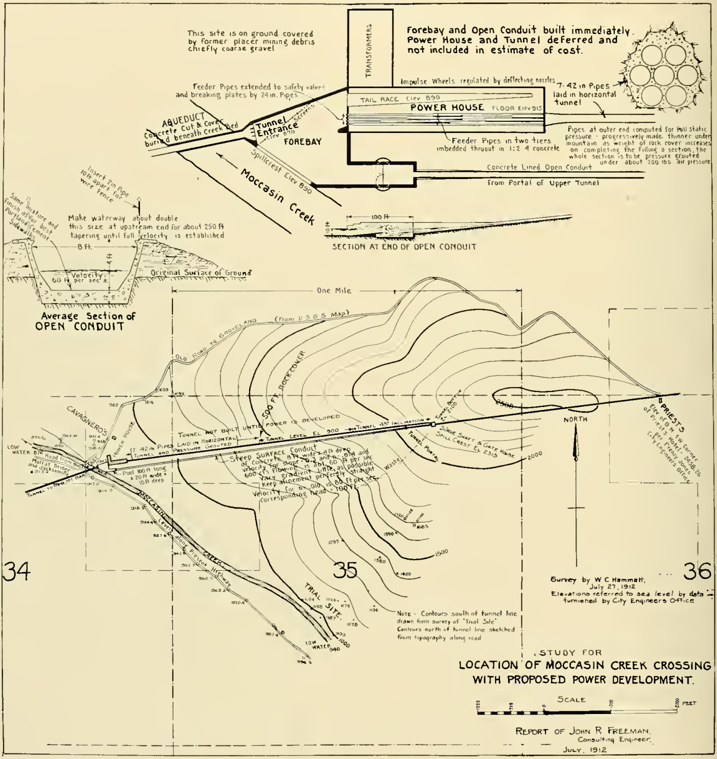
Near the east end, the tunnel enters a bed of Mariposa slate, which occupies the valley of Moccasin Creek. This bed has an easterly dip of about 60 degrees, and the outward appearance of the rock is not so good as that previously referred to between Miles 132 to 134. The dip being not so nearly vertical as in the former case is unfavorable to stability in the tunnel roof, and it can reasonably be expected that the portion through slate will have to be lined for its full length.

For about 1.5 miles easterly from the river crossing the ground looked favorable for the use of the less expensive cut and cover type of construction instead of tunnel, thereby making a saving from the cost as now estimated.

The above described tunnel work has been classified and estimated to cost as follows:

12,900 lineal feet through amphibolite, with 10 per cent of length tim-

Carried forward $14,282,400



STUDY FOR
LOCATION OF MOCCASIN CREEK CROSSING
WITH PROPOSED POWER DEVELOPMENT.

Forebay and Open Conduit built immediately. Power House and Tunnel deferred and not included in estimate of cost.

This site is on ground covered by former placer mining debris chiefly coarse gravel

Pipes at outer end computed for full static pressure - progressively made thinner under mountain as weight of rock cover increases on completing the filling a section, the whole section is to be pressure grouted under about 200 lbs air pressure

Make waterway about double this size at upstream end for about 250 ft tapering until full velocity is established

Steep Surface Conduit of concrete 8 ft wide x 4 ft deep for slope 0.2 and n .014 and velocity flowing 600 cfs is abt. 60 ft per sec Vary gradient little, as possible Keep alinement perfectly straight Velocity for n .010 is 80 ft per sec. Corresponding head 100 ft.

Note - Contours south of tunnel line drawn from survey of "Trial Site" Contours north of tunnel line sketched from topography along road

Survey by W C Hammatt,
July 27, 1912
Elevations referred to sea level by data furnished by City Engineers Office

Report of John R Freeman,
Consulting Engineer,
July, 1912

TRANSFORMERS
Impulse Wheels regulated by deflecting nozzles
Feeder Pipes extended to safety valves and breaking plates by 24 in. Pipes
TAIL RACE Elev 890
POWER HOUSE FLOOR Elev 915
7-42 in Pipes laid in horizontal tunnel
Feeder Pipes in two tiers imbedded thruout in 1:2 4 concrete
AQUEDUCT Concrete Cut & Cover buried beneath Creek Bed
Screens
Tunnel Entrance Elev 870
FOREBAY
Spillcrest Elev 890
Moccasin Creek
Concrete Lined Open Conduit
from Portal of Upper Tunnel
100 ft
10 ft
SECTION AT END OF OPEN CONDUIT
Insert 2 in Pipe 10 ft apart for wire fence
Same mixture and finish as for best Portland Cement Sidewalks
8 ft.
4 ft
Velocity 60 ft per sec ±
Original Surface of Ground
Average Section of OPEN CONDUIT
One Mile
Old Road to Groveland (From U S G S Map)
500 FT. ROCK COVER
CAVAGNERO'S
POWER HOUSE
Tunnel not built until power is developed
7 42 in Pipes laid in horizontal tunnel and pressure grouted
Tunnel Level El 900
Tunnel 45° Inclination
Tunnel Bottom El 2100
Surge Shaft & Gate House Spill Crest El 2315
Tunnel Portal
Waste
Pool 100 ft long x 20 ft wide x 10 ft deep
LOW WATER 876
Road from Moffat Bridge and Jacksonville
Tunnel to Red Mt Bar
MOCCASIN CREEK
Level along Present Highway
TRIAL SITE
LOW WATER 940
NORTH
PRIESTS
Elev of B M SW Corner of Priest's Hotel 2458.26 per Frenzy Jones City Engineers Office
2500
2000
1500
1400
1000
34
35
36
SCALE
1000
500
0
1000
2000
FEET

Brought forward	$14,282,400
bered, at $31.00	399,900
1,300 lineal feet through serpentine, 60 per cent to be timbered, at $38.00	49,400
13,300 lineal feet through porphyrite, with 10 per cent of length timbered, at at $32.50	432,300
1,800 lineal feet through Mariposa slate, 100 per cent timbered, at $43.00	77,400

(12) Probably one or more shafts will be driven for the convenient working of the above tunnel, but as no sites were seen that were naturally adapted to the purpose none have been noted on the maps, and the subject is a matter for further investigation.

It is fair to estimate at least 600 lineal feet double compartment shaft, at $125.00 — 75,000

The most convenient and nearest railroad point to this work is one of the stations on the Sierra Railroad—either Keystone or Rosasco.

The district between the Tuolumne River and Moccasin Creek is particularly difficult of access for heavy freight wagons, because it is almost completely surrounded by deep canyons. The country presents hard conditions for obtaining roads of moderate grades, and as it is only very sparsely settled, little has been done in that direction. The steepness of the hills on the existing roads is practically prohibitive to hauling any but the lightest loads. The construction of nearly ten miles of new road crossing the Tuolumne River, near Red Mountain Bar, is essential to the economical construction of the last-named tunnel portion of the aqueduct. The new road is assumed to begin at Rosasco Depot and to extend to a connection with the Marsh Flat road, at a probable shaft site near mile 137.6.

It will not be very difficult to construct a road, with maximum grade not exceeding 6 per cent for a cost of from $3,000 to $4,000 per mile, exclusive of road bridge across the Tuolumne River. By extending the piers of the pipe bridge so as to accommodate the road, a concrete highway bridge,

Carried forward $15,316,400

Brought forward $15,316,400

with 100-foot spans, can be built for about $35,000, making a total cost for 10 miles of new road and bridge, say 75,000

Total construction cost of the Valle-Moccasin Division, exclusive of general administration, heavy plant and contractor's profit $15,391,400

Ninth Division, Moccasin-Early Intake

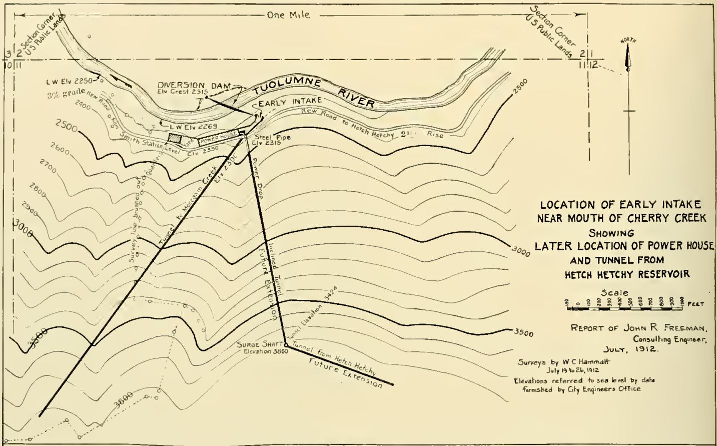
This division extends from the east end of Moccasin Tunnel at mile 140.2 to the Tuolumne River at a point one and one-half miles up river from the mouth of Cherry Creek, at mile 159.7 of the aqueduct.

The main feature of the work is a pressure tunnel ten feet in diameter and 18.5 miles long, broken into two sections by the 1,700 feet of 10-foot steel pipe siphon required at the crossing of South Fork.

Structures to divert the Tuolumne water into the tunnel, such as a low dam and an intake to the tunnel, with gates to regulate the flow, must be constructed at the easterly end of the tunnel. The western terminus of the tunnel will be at the face of the abrupt slopes of Moccasin Creek canyon and at an elevation of approximately 1,250 feet above the creek bed. It is proposed to utilize this drop at some time in the future for a power development, and to do so will require a connection from the tunnel to the proposed power station, to be made either by an incline pressure tunnel, built in the hill well back from the face of the bluff and where the rock is solid and firm, or if the rock formation should prove too seamy and open to make this suggestion practicable, steel pipes would have to be substituted for a part, or all, of the proposed incline tunnel, according to the quality of the rock, as it may be determined by future study in conjunction with borings and expert geological advice.

Although the power development is deferred indefinitely, some of the structures required for that development are immediately essential to the operation of the aqueduct, exclusive of the power plant feature. These are the concrete chute from the mouth of the tunnel to the foot of the slope at Moccasin Creek, and the equalizing pool below the proposed power house. See plan, page 280.

Our information as to the nature of the tunnel work has been derived from a hasty trip over the line and a brief geological study and report by Professor J. C. Branner. We learn from the report that the main tunnel will traverse the varying rocks from west to east in the order and for about the distances given, as follows:



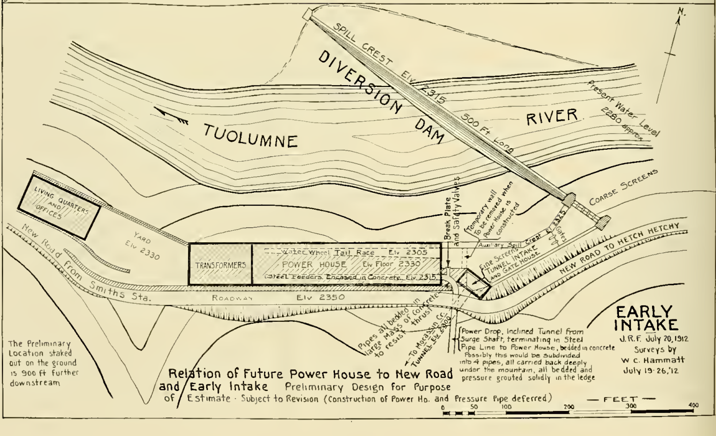
LOCATION OF EARLY INTAKE
NEAR MOUTH OF CHERRY CREEK
SHOWING
LATER LOCATION OF POWER HOUSE
AND TUNNEL FROM
HETCH HETCHY RESERVOIR

REPORT OF JOHN R FREEMAN,
Consulting Engineer,
JULY, 1912.

Surveys by W C Hammatt
July 19 to 26, 1912

Elevations referred to sea level by data furnished by City Engineers Office

One Mile
Section Corner U.S. Public Lands
Section Corner U.S. Public Lands
NORTH
TUOLUMNE RIVER
DIVERSION DAM Elv Crest 2315
EARLY INTAKE
L W Elv 2250
3% grade New Road to Smith Station
L W Elv 2269
Yard
POWER HOUSE
Steel Pipe Elv 2315
Smith Station Level Elv 2350
New Road to Hetch Hetchy 2½% Rise
Tunnel to Moccasin Creek Elv 2300
Power Drop
Inclined Tunnel Future Extension
Survey line brushed out
Quarters
Tunnel Elevation 3424
SURGE SHAFT Elevation 3800
Tunnel from Hetch Hetchy Future Extension
Scale
FEET
2500
2600
2700
2800
2900
3000
3500
3800



EARLY INTAKE
J.R.F. July 20, 1912
Surveys by W. C. Hammatt
July 19-26, '12

Relation of Future Power House to New Road and Early Intake Preliminary Design for Purpose of Estimate · Subject to Revision (Construction of Power Ho. and Pressure Pipe deferred)

The Preliminary Location staked out on the ground is 900 ft further downstream

Power Drop, Inclined Tunnel from Surge Shaft, terminating in Steel Pipe Line to Power House, bedded in concrete. Possibly this would be subdivided into 4 pipes, all carried back deeply under the mountain, all bedded and pressure grouted solidly in the ledge

N.
SPILL CREST Elv 2315
DIVERSION DAM 500 Ft Long
TUOLUMNE RIVER
Present Water Level 2280 approx.
COARSE SCREENS
LIVING QUARTERS AND OFFICES
YARD Elv 2330
New Road from Smiths Sta.
TRANSFORMERS
Water Wheel Tail Race Elv 2305
POWER HOUSE Elv Floor 2330
Steel Feeders Encased in Concrete Elv 2315
ROADWAY Elv 2350
Break Plate and Safety Valves
Temporary wall to be removed when Power House is constructed
Auxiliary Spill Crest El. 2323
Gates
Fine Screens
TUNNEL INTAKE AND GATE HOUSE
NEW ROAD TO HETCH HETCHY
Pipes all bedded in large mass of concrete to resist thrust
To Moccasin Cr. Tunnel El. 2300
FEET
0
50
100
200
300
400

Mile	Formation	Length
Mile 141.2-142.6,	Porphyrite	7,400 ft.
" 142.6-145.3,	Calaveras quartzite, schist and shale interbedded	14,260 "
" 145.3-146.3,	Granite	5,280 "
" 146.3-150.0,	Calaveras quartzite, etc.	19,540 "
" 150.0-150.5,	Andesite tuff	2,640 "
" 150.5-154.0,	Calaveras quartzite, etc.	18,480 "
" 154.0-154.25,	Granite and Granodiorite	1,320 "
" 154.25-154.6,	South Fork siphon	1,700 "
" 154.6-159.7,	Granite and Granodiorite	27,060 "
	18.5 miles, or	97,680 ft.

Note: There is a discrepancy between the mileage above given and that appearing in Professor Branner's report, because of a change in the location of the aqueduct line made subsequent to the date of that report.

So far as judgment could be formed from a very hurried surface inspection of the ground it appears that the tunneling will vary from good to poor, according as the rock may be hard or soft, and dry or wet, but at no place was evidence noted that any difficulties of more than ordinary occurrence in nearly every tunnel of considerable length through variable material, need be anticipated.

The Calaveras formation, particularly at contact planes and in wet places, will probably give the most trouble of any, but nothing worse or even as bad as will be found at places in the Coast Range tunnels.

The tunnel can be worked from a number of shafts and adits, but there will be one stretch of four miles and another of five miles between openings. The work has been subdivided and estimated as follows:

(1)	For lower pool and tunnel intake at Moccasin Creek—	
	15,000 cubic yards earth and cobbles, excavation, at 40 cents	$ 6,000
	22,000 cubic yards slate rock excavation, at 90 cents	19,800
	4,600 cubic yards concrete in walls, at $7.00	32,200
	Piers, sluice gates, screens, etc., for intake	4,300
	Gate house and keeper's cottage, etc.	4,000
(2)	For inclined water chute, 4,920 feet long—	
	4,000 cubic yards excavation, at 50 cents	2,000
	3,500 cubic yards backfill, at 40 cents	1,400
	2,300 cubic yards concrete, at $9.00	20,700
	65,000 square feet surface finish, at 4 cents	2,600
	10,000 lineal feet railing, pipe and woven wire, at 21 cents	2,100
	Carried forward	$95,100

	Brought forward	$95,100
(3)	Groveland Tunnel, 68,900 lineal feet 10-foot diameter, extending from mile 141.2 to 154.25, subdivided as to the several formations passed through, is estimated to cost as follows:	
	7,400 lineal feet of main tunnel through porphyrite, 10 per cent timbered, at $32.00	236,800
	52,280 lineal feet through Calaveras quartzite, schist and shales interbedded, 70 per cent timbered, at $36.00	1,882,100
	2,640 lineal feet through Andesite tuff, 20 per cent timbered, at $24.00	63,400
	6,600 lineal feet through granite, 15 per cent timbered, at $32.00	211,200
(4)	At the crossing of the South Fork Canyon the tunnel grade is about 640 feet, and the maximum hydraulic gradient approximately 710 feet above the bed of the stream. The following estimate provides for a single line of 10-foot diameter steel pipe laid on the sloping sides of the canyon and carried across the river on a massive concrete bridge at an elevation 40 feet above bottom. The pipe to be cement lined on the interior. Add 500 feet to horizontal distance for extra length and dip of pipe and for overlap at the tunnel ends.	
	1,300 lineal feet 13/16-inch shell (average head 365 feet), at $49.60	64,500
	400 lineal feet 1 7/16-inch shell (maximum head 670 feet), at $64.00	25,600
	Concrete arch bridge, two 100-foot spans, across river	12,100
(5)	27,060 lineal feet 10-foot diameter concrete lined tunnel through hard granite, 5 per cent timbered, at $34.00	920,000
(6)	The tunnel runs deep below the ground surface for nearly 10 miles eastward from Priests Hotel, also for more than 5 miles easterly from South Fork, and for upwards of nine miles the depths below surface range from 800 to 1,600 feet. Shafts have been located at all low places where the depression of the ground will keep the shaft within	
	Carried forward	$3,510,800

Brought forward $3,510,800

reasonable depth. Two shafts 700 feet and 540 feet deep have been located at Second Garotte and Big Creek, respectively. Other portions of the tunnel can be worked from adits not to exceed 300 to 500 feet in length, and from four portals, one at Moccasin Creek, two at South Fork, and one at the Tuolumne Intake. There will be two stretches of this tunnel of 4 and 5 miles between openings.

1,240 lineal feet double-compartment shafts, timbered full depth, at $150	186,000
2,600 lineal feet 6-foot tunnel for six adits, unlined, but each plugged with concrete for 40 feet in length at completion of work	....
2,600 lineal feet tunnel excavation, at $14.00	36,400
480 cubic yards concrete refill, at $7.80	3,700

(7) The headworks for the "Early Intake" from the Tuolumne River will consist of a diverting dam, short canal and forebay, with sluiceways guarded with coarse screens and regulating gates, also screen house with fine screens at entrance to tunnel. The proposed dam is to be a solid concrete overflow dam of ogee section, with spill-crest 500 feet long. The maximum height will be approximately 45 feet above bedrock foundation for 250 feet across the river channel. Preparation of foundation for main dam, including—

Excavation and foundations for flume	$ 1,500
Flume and diversion dam	4,000
2,100 cubic yards boulders and rock excavation in river bed, at $2.00	4,200
2,300 cubic yards mixed excavation on banks, at $1.00	2,300
Grout and drain holes	1,200
10,960 cubic yards concrete in main dam, at $8.00	87,700
1,400 cubic yards concrete in auxiliary structures, at $10.00	14,000
3,000 cubic yards rubble stone placed in concrete, at 50 cents	1,500
Screen house, sceeens, gates, etc	3,500

Carried forward $3,856,800

Construction cost of the Moccasin-Early Intake Division, exclusive of general administration, heavy plant, and contractor's profit $3,856,800

Tenth Division, Canyon Division

This, the final section of the Hetch Hetchy Aqueduct, extends from the site of a future power station location immediately below the "Early Intake" to a connection with the Hetch Hetchy Reservoir—mile 159.7 to mile 171.8.

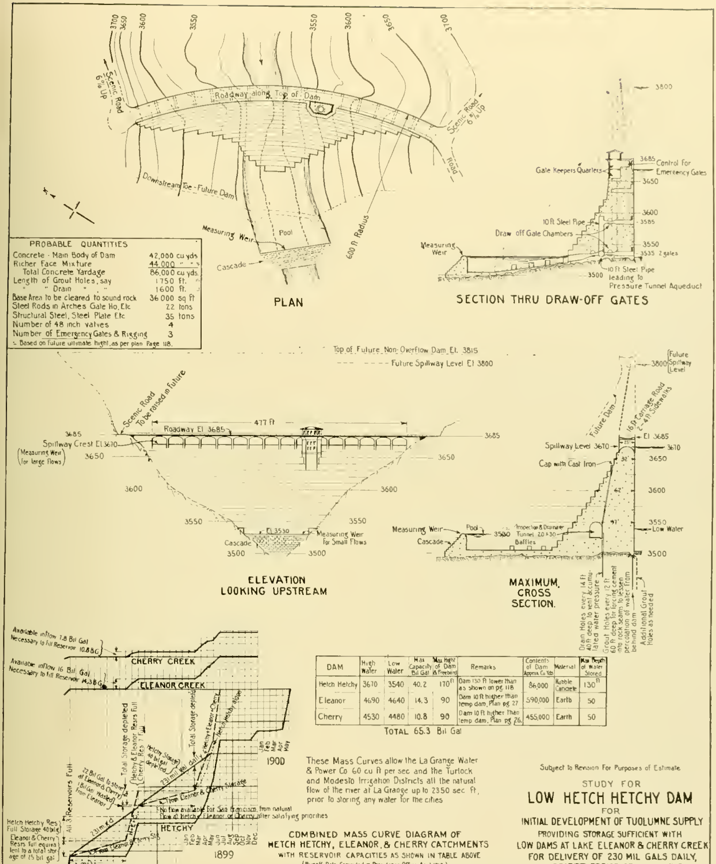
This portion of the aqueduct does not become an essential feature of the project of delivering Hetch Hetchy water to San Francisco until such time as the objections to the occasional turbidity due to heavy rainfalls on the canyon slopes between the Hetch Hetchy Dam and the Early Intake shall make it worth the cost to keep the water continuously under cover from the time it leaves the reservoir until it reaches the receiving reservoirs in San Francisco. Since the demand for this improvement in the quality of the water is not likely to develop for many years, it is scarcely necessary to consider the cost of this division and to charge it in the present estimate. However, as it is a part of the ultimate plan, a note is now made of the cost in order to be able to give a total for the Hetch Hetchy project considered as a whole.

When this section is built it will be feasible to utilize the 1,500-foot drop, which exists between Hetch Hetchy Reservoir and Early Intake.

It is proposed to do this by conducting the water through an incline tunnel from its high level at the west end of the main tunnel, to the lower level of the future power house, in a manner similar to that proposed at Moccasin Creek.

Both the incline and the main tunnel will be wholly in the firm and hard gray granite that forms the bedrock of that whole region. The rock is dense, close-grained and massive, being so far as observed notably free from open seams. It is a most excellent formation in which to locate a pressure tunnel, such as the incline to the power house. It is also an excellent rock to tunnel through, the only objection to it, if any, being that it is too hard, entailing high costs for drilling and powder, also by its hardness limiting the rate of progress to somewhat less than can be made in softer ground. On the other hand, we are assured that this rock will not give rise to any vexatious or dangerous conditions. The tunnel will be safe and dry, and will require practically no timbering. The rock is so close-grained and uniform in character that in the blasting it probably will break true to line, thus making a saving in concrete.

As a part of the power plant it is designed to have a surge tank about 330 feet deep at the west end of the main tunnel


3700
3650
3600
3550
3550
3600
3650
3700
3800
Scenic Road 6% Up
Roadway along Top of Dam
Scenic Road 6% Up
Road
Downstream Toe - Future Dam
Measuring Weir
Pool
Cascade
600 ft Radius
3685 Control for Emergency Gates
Gate Keepers Quarters
3650
3600
10 ft Steel Pipe
3585
Draw off Gate Chambers
3550
3535 2 gates
Measuring Weir
10 ft Steel Pipe leading to Pressure Tunnel Aqueduct
3500
Top of Future Non-Overflow Dam El. 3815
Future Spillway Level El 3800
Scenic Road To be raised in future
477 ft
Roadway El 3685
3685
Spillway Crest El 3670
Measuring Weir for large flows
3650
3600
3550
El 3530
Measuring Weir for Small Flows
Cascade
3500
Future Spillway Level
3800
Future Dam
16 ft Carriage Road 2-4 ft Sidewalks
El 3685
Spillway Level 3670
3670
Cap with Cast Iron
3650
3600
3550
Low Water
3500
15'
32'
62'
97'
Measuring Weir
Pool
3530
Inspection & Drainage Tunnel 20 x 30
Baffles
Cascade
Drain Holes every 14 ft 40 ft deep to vent accumulated water pressure
Grout Holes every 12 ft 60 ft deep for forcing cement into rock seams to lessen percolation of water from behind dam
Additional Grout Holes as needed
Available inflow 7.8 Bil Gal Necessary to fill Reservoir 10.8 B G
CHERRY CREEK
Available inflow 16 Bil Gal Necessary to fill Reservoir 14.3 B G
ELEANOR CREEK
Total Storage depleted
Hetchy & Eleanor Resrs Full Cherry Res 7 Full
Total Storage depleted
Hetchy + Eleanor + Cherry
Hetch Hetchy alone
Hetchy Storage 40 bil gal depleted
231 mil gal daily
22 Bil Gal to store at Eleanor & Cherry
1 Bil Gal Wasted from Eleanor
From Eleanor & Cherry Storage
No flow available for San Francisco from natural flow at Hetchy, Eleanor or Cherry after satisfying priorities
All 3 Reservoirs Full
Hetch Hetchy Res Full Storage 40 bil g
Eleanor & Cherry Resrs full equivalent to a total storage of 25 bil gal
231 m.g.d.
H+E+C
Eleanor & Cherry St
HETCHY
No flow available for San Francisco from natural flow at Hetchy, Eleanor or Cherry after satisfying priorities
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1898
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1899
Jan Feb Mar Apr May
1900
0 50 100 150 200 250 300 350 400

PROBABLE QUANTITIES	
Concrete - Main Body of Dam	42,000 cu yds
Richer Face Mixture	44,000 " "
Total Concrete Yardage	86,000 cu yds
Length of Grout Holes, say	1750 ft.
" Drain " "	1600 ft.
Base Area to be cleared to sound rock	36 000 sq ft
Steel Rods in Arches Gate Ho. Etc	22 tons
Structural Steel, Steel Plate Etc	35 tons
Number of 48 inch valves	4
Number of Emergency Gates & Rigging	3

* Based on future ultimate hight, as per plan Page 118.

PLAN

SECTION THRU DRAW-OFF GATES

ELEVATION
LOOKING UPSTREAM

MAXIMUM
CROSS
SECTION.

DAM	High Water	Low Water	Max Capacity Bil Gal	Max Hight of Dam & Freebord	Remarks	Contents of Dam Approx Cu Yds	Material	Max Depth of Water Stored
Hetch Hetchy	3670	3540	40.2	170 ft	Dam 130 ft lower than as shown on pg 118	86,000	Rubble Concrete	130 ft
Eleanor	4690	4640	14.3	90	Dam 10 ft higher than temp dam, Plan pg 27	590,000	Earth	50
Cherry	4530	4480	10.8	90	Dam 10 ft higher than temp dam, Plan pg 26.	455,000	Earth	50

TOTAL 65.3 Bil Gal

These Mass Curves allow the La Grange Water & Power Co 60 cu ft per sec and the Turlock and Modesto Irrigation Districts all the natural flow of the river at La Grange up to 2350 sec ft, prior to storing any water for the cities

COMBINED MASS CURVE DIAGRAM OF
HETCH HETCHY, ELEANOR, & CHERRY CATCHMENTS
WITH RESERVOIR CAPACITIES AS SHOWN IN TABLE ABOVE
(Runoff Data Computed in Providence Office April 1912)

Smallest Runoff since Lagrange Gagings

Scale of Feet

Subject to Revision For Purposes of Estimate

STUDY FOR
LOW HETCH HETCHY DAM
FOR
INITIAL DEVELOPMENT OF TUOLUMNE SUPPLY
PROVIDING STORAGE SUFFICIENT WITH
LOW DAMS AT LAKE ELEANOR & CHERRY CREEK
FOR DELIVERY OF 230 MIL GALS DAILY,
IN DRIEST PERIOD OF LAST 17 YEARS

John R Freeman, Consulting Engr
Providence, R I.
Aug 1912

R.E. Cranston

and as nearly as may be over the head of the incline. This tank will consist mainly of a shaft in the rock provided with a concrete spill and chute down to the river. But until the power is utilized these structures will not be needed, and during the intervening period the water can be discharged from the end of the main tunnel, letting it fall in a series of cascades over the rocky slope of the canyon to the river, 1,100 feet below.

The main tunnel approximately parallels the course of the south side of the Tuolumne Canyon, being located far enough back from the side to give sufficient weight of rock to safely resist the bursting pressure of the water in all parts of the tunnel.

In addition to the two ends, other working points which will increase the convenience and speed of construction can readily be obtained by means of adits or shallow shafts at suitable places. With the present incomplete information, it is assumed that adits will be generally adopted as likely to give the most economical results.

Including the one at the west end of the tunnel, allowance has been made for 14 adits, with an aggregate length of 5,700 feet. Considering the short length of each adit, probably a tunnel large enough to accommodate a single-track railway will be ample for all requirements, and the 6-foot horseshoe section has been assumed as suitable. The adits to be excavated to full size for concrete-lined tunnel, but the lining will be omitted. On completion of the work the openings will be plugged tight with concrete for lengths of from 40 to 60 lineal feet, according to the varying pressure on the tunnel. Ten per cent of the length of adits has been estimated as timbered.

Following is the estimate of cost of 11.7 miles main tunnel and adits, being the only structures necessary prior to the power development at the Early Intake site.

61,800	lineal feet 10-foot diameter pressure tunnel, 5 per cent timbered, and concrete-lined for full length, at $37.00	$2,286,600
5,700	lineal feet 6-foot tunnel for adits, 10 per cent timbered, no concrete lining, at $14.50	82,700
1,630	cubic yards concrete for closures of adits, at $8.00	13,000
	Construction cost of the Canyon Division, exclusive of general administration, heavy plant, and contractor's profit	$2,382,300

Eleventh Divison, Hetch Hetchy Dam and Reservor

For the immediate requirements of an additional supply of 230 million gallons daily a dam somewhat lower than is needed for the complete development of the storage will be adequate for several years to come, and it is proposed to defer a part of the cost of the structure until such future time as the high dam may become a necessity.

It is estimated that a dam 170 feet high above river bed would impound 40,000 million gallons, and that this storage is sufficient to maintain a uniform daily supply of 230 million gallons. This lower dam would have a crest length of about 500 feet at elevation 3,760, with length shortening to about 200 feet at elevation 3,500, and would require only 86,000 cubic yards of concrete for its construction.

Eventually, when it becomes necessary to develop the Hetch Hetchy Reservoir to its full capacity, so as to be able to supply 400 million gallons daily, it is designed that the final dam shall have a height of approximately 300 feet above the river bed to spill-crest at elevation 3,800. This dam would contain 372,000 cubic yards of concrete masonry, and impound 110,000 million gallons of water. (See drawings on page 118.)

The lower structure is designed in such a manner that it can be readily and safely incorporated as a part of the final dam when that is built. (See drawing on page 285.)

The estimated cost of this division is based on the use of the lower dam, and the principal items of cost have been considered and estimated as follows:

(1) *Clearing Reservoir Site.*

The total area of the reservoir will be nearly 1,300 acres, of which not more than 300 acres will have to be cleared by cutting trees and brush close to the ground, removing logs, and burning brush. Some of the cost can be recovered by converting the large trees into lumber to be used for construction purposes.

300 acres of clearing, at $100.	$30,000

(2) *Camp Buildings.*

Temporary buildings, dwellings, bunkhouses and field offices, not including power plant, cement sheds, shops, etc.	20,000
Camp equipment	3,200
Camp light and telephone connections. . . .	700
Water supply and pump connections.	1,500
Sewers and sewage disposal.	800
Total	$26,200

(3)	Roads about camp and to gravel pit, quarry, etc.	$2,500

(4) *Camp Maintenance and Repairs.*

(For, say two years.)

Office furnishings, supplies, etc.	$2,000
Carried forward	$2,000

Brought forward	$2,000
Entertainment, including maintenance of Superintendent's house	4,000
Loss on boarding-house secures better men, say	7,500
(This can be wholly recovered by profit in commissary.)	
Maintenance and repairs of camp buildings and stable	3,000
Maintenance hospital, physician, etc. (loss)	2,500
Policing camp	5,000
Light, water and telephone maintenance	3,000
Miscellaneous incidentals, etc.	5,000
	$32,000

(5) *Construction Plant Buildings.*

Cement storage sheds	$1,500
Concrete plant, buildings, and foundations, for mixing and conveying machinery, including winter protection	3,000
Power plant, buildings, and foundations for machinery	2,500
Mechanical shop buildings, warehouses, etc.	3,000
Total	$10,000

(6) *Preparation of Foundations.*

The dam site above water is sound granite, scoured clean by glacial action, and needs but little excavation of earth or scab rock. No diamond drill borings have been made in the bed of the stream, but although the gorge may prove to be deep it is surely narrow.

Assume 3,000 cubic yards mostly ledge and boulders will have to be excavated, some in cut-off trench and some from river bed, at $2.00	6,000
Cleaning 36,000 square feet of generally sound bottom to receive concrete, say	1,700
Drifting behind and grouting loose block of granite on north side	1,500
Grout Holes—The extent of grouting depends on the character of the rock. The excellent foundations should allow us to assume only the equivalent of 30 holes 60 feet deep, or 1,800 feet, at 50 cents for drilling, plus 75 cents for grout and grouting, or $1.25	2,300
Carried forward	$11,500

Brought forward	$11,500
Drain Holes—Like grout holes, depend on character of rock, say 1,600 feet, at 80 cents, including all drain pipe in place	1,300

Adit and beginning of future tunnel aqueduct:

200 lin. ft. 6-ft. tunnel unlined and not plugged at completion of dam @ $15.40	3,100
130 lin. ft. 10-ft. tunnel in granite @ $43.00	5,600
220 lin. ft. 12-ft. tunnel for pipe connection—refilled around pipe with concrete @ $37.00	8,100
545 cu. yds. concrete refill @ $7.00	3,800
280 lin. ft. 10-ft. steel pipe ¼ in. shell to connect present tunnel with gate chamber @ $20.00	5,600
Total	$39,000

(7) *Water Control During Construction.*

The foundations of the dam will contain a sluice tunnel for the passage of the river. Preliminary flume	$10,100
Preliminary coffer dams, pumping and miscellaneous	6,000
Total	$16,100

(8) *Masonry in Main Dam and Appurtenances.*

The main body of the dam to be built of concrete, but large stones will be used so far as can be done to advantage. There is every indication that large deposits of good gravel can be found nearby and if sufficient in quantity it may prove quicker and cheaper to build the dam almost entirely of gravel concrete, using few if any "plums", but, for the purpose of this estimate, assume the dam to be 20% "plums".

It is believed that a concrete leaner in cement than is usually specified, is entirely suitable for the heart of the dam, and that it is much better to increase the safety by increasing the thickness of the dam toward the base, rather than to use a thinner section richer in concrete. A richer concrete will be used on the faces of the dam and this estimate assumes that the richer concrete used will be equivalent to an average thickness of ten feet applied over the entire vertical face of the dam. This, however, may be disposed within a thickness of eight feet on the upstream face for imperviousness and two feet in thickness over the downstream face for resistance to weather and smoothness of finish.

The two grades of concrete are assumed proportioned by measure to be 1 part cement to 3 1/3 sand, and 6 2/3 stone for the lean and 1:3:5 for the rich mixture.

Assuming that a gravel bank yielding from 30 to 40 per cent suitable gravel can be found within one mile of the work and that it is worked by steam shovel and train we have for probable cost of gravel, broken stone and sand,

(*a*) 1 cu. yard in place contains say 35% small stones, 40% sand and 25% cobbles and boulders—with 40% voids in the gravel screened it will require the excavation of 2 cu. yards in place for each yard of screened gravel obtained.

(*b*) Cost of screened gravel, excavation and loading by steam shovel including stripping pit	$ .18
Track work at pit and spotting cars	.05
Hauling to bins and screening	.08
Cost of excav. for 1 cu. yd. in place yielding 0.49 cu. yd. screened gravel	.31
The cobbles can be run thru a crusher, and will make about 0.4 cu. yd. of additional concrete stone for...	.15

0.4 cu. yd. sand, or nearly enough to form the proper mixture with the above 0.89 cu. yds. of stone will be obtained as a by-product, we may say without cost.

Since 0.89 cu. yd. of broken stone and gravel costs 46 cents the per cu. yd. cost will be	.52

Allow for shortage and handling of sand 20c per cu. yd. The cement is estimated to cost $3.00 per bbl. delivered at the dam.

With the above assumption the cost of 1 cubic yard of 1:3 1/3:6 2/3 concrete will be:

1.0 bbls. concrete	@ $3.00	$3.00
0.53 cu. yds. sand	@ .20	.11
0.94 cu. yds. stone	@ .55	.52
Mixing and placing		.60
Lumber and bolts in forms		.20
Carpenter work, setting forms, staging, etc.		.25
		$4.68

Say $4.75 per cu. yd. of concrete in place.

For the 1:3:5 concrete, each cubic yard will require about 1.25 bbls. cement, 0.48 cubic yards sand and 0.81 cu. yd. stone, which in a similar way is estimated to cost $5.30 per cubic yard in place.

The quantity of concrete to go in the main dam and spillway is 88,200 cubic yards. For this there will be 18,000 cu. yds. plums from quarry at site of future waste-way.

Quarrying and placing 18,000 cu. yds., $2.00		$36,000
34,400 cu. yds. concrete, 1:3 1/3:6 2/3 mixture	@ 4.75	163,400
35,800 cu. yds. concrete, 1:3:5 mixture	@ 5.30	189,700
Carried forward		$389,100
Brought forward		389,100
2,200 cu. yds. in smaller structures of richer concrete and some additional cost for forms and placing	@ 7.50	16,500
Steel reinforcements in crest of main dam and arches, also lining for outlet conduits, 60 tons	@ .80	4,800
Total		$410,400

(9)	*Gates and Accessories.* Five 48-inch gates; two balanced pressure gates for tunnel connection; three emergency gates (roller type), operating mechanism for gates; steel and cast iron pipe connections, screens, etc.	$45,000
(10)	*Plant Maintenance and Repairs.* Repairs to cars, skips, tools, etc. (consider repairs to the power plant and line after a severe winter and possible dismantling of the cableways at season's end), say	$40,000
(11)	Landscape architectural treatment near dam, and necessary cleaning up	$10,000
(12)	*Local Superintendence and Engineering* These local overhead charges will amount to very nearly 5% of the cost of the preceding items	$31,700

SUMMARY FOR A LOW HETCH HETCHY DAM

(With spillcrest at about elevation 3670)

(1)	Clearing reservoir site	$30,000
(2)	Camp buildings, dwellings and offices	26,200
(3)	Construction roads	2,500
(4)	Camp maintenance and repairs	32,000
(5)	Temporary buildings for construction plant	40,000
(6)	Preparation of foundations, including preliminary work on future pressure tunnel	39,000
(7)	Water control during construction	16,100
(8)	Masonry in main dam and accessories, Portland cement concrete mainly made from gravel, 20% "plums" bedded in the body of the large structures	410,400
(9)	Draw-off gates and accessories, and steel lining of conduits	45,000
(10)	Plant maintenance and repairs	40,000
(11)	Landscape architectural treatment near dam	10,000
(12)	Engineering, superintendence and contingencies	34,600
	Construction cost of Hetch Hetchy Division, exclusive of administration, heavy plant and contractor's profit	$725,800

Twelfth Division, Eleanor-Cherry

The work on this division comprises an unlined pressure tunnel 8 feet diameter and 6.8 miles long; two earth fill dams at Cherry Creek and Eleanor Lake outlet, a shaft about 300 feet deep at Lake Eleanor, and intake works at Cherry Creek and Lake Eleanor. On completion of the tunnel the shaft will be adapted to serve as an intake for Eleanor water. The underlying bedrock in this district is hard granite or granodiorite throughout.

(1)	35,900 lin. ft. 8-foot tunnel 5 per cent timbered, no lining @ $20.50	$736,000
(2)	300 lin. ft. double compartment shaft @ 150.00	45,000
(3)	Lake Eleanor Dam and Reservoir—Earth fill dam 90 feet high and 1200 ft. long on crest, containing 59,000 cu. yds. to be built in part by hydraulic sluicing. This item also includes the cost of excavating of unsuitable foundation material at the dam site; a reinforced concrete core-wall, concrete overflow weir, with sluice gates, waste channel in rock, and an arch bridge over spill-way; also rock fills at foot of slopes of main earth dam, slope paving, care of water during construction, clearing timber, residence and stable for keeper, and miscellaneous	$431,000
	Gate house, screens, gates, etc., for tunnel intake	28,000
(4)	*Cherry Creek Dam and Reservoir.*	
	Earth fill dam 90 ft. high and 1,040 feet long on crest, containing 455,000 cu. yds. of earth, to be built in part by hydraulic sluicing. This item also includes the cost of excavation of unsuitable foundation material at the dam site; a reinforced concrete core-wall, concrete overflow weir, with sluice gates, waste channel in rock and an arch bridge over spill-way; also rock fills at foot of slopes of main dam, slope paving, care of water during construction, and miscellaneous	$388,000
	Gate tower, gates, screens, etc., for shaft intake to tunnel	28,000
	Carried forward	$1,656,000
	Brought forward	$1,656,000
	For construction cost of Eleanor-Cherry Division, exclusive of administration, heavy plant and contractor's profit	$1,656,000

Facilities for Transportation of Equipment and Materials

For a distance of about 130 miles between San Francisco and the foothills of the Sierras the working points on the aqueduct are within easy reach from the existing railroads. The length of haul will not generally exceed four or five miles, and only in two instances is the distance from the railroad as much as nine miles. The public roads are generally good and but little additional road work will be necessary.

From the entrance to the foothills to Hetch Hetchy, however, the facilities for reaching the work are not so good.

The nearest railroad stations to the mountain district traversed by the aqueduct, easterly from Mile 134, are Rosasco, Keystone and Chinese, on the Sierra Railway, each about 42 miles in an air line from Hetch Hetchy dam site.

Traffic to and from this district passes mainly through Chinese, from which point a road runs to Groveland and to points beyond, including Yosemite Valley, also a branch to Hog Ranch, the latter place being the nearest point to the Hetch Hetchy Valley now accessible to teams.

The Hetch Hetchy dam site lies about seven miles easterly from the Hog Ranch and is reached only by a rough mountain trail. Were it not for the steep hills, the road from Chinese to Hog Ranch would serve the work conveniently for a distance of about 12 miles, from Moccasin Creek to the crossing of Big Creek, but elsewhere it is most unfavorably located for ready access to the line of the aqueduct, and about 29 miles of the aqueduct in the mountain region may be said to be wholly out of reach of existing roads.

Considering the possible utility of the present main road from Chinese to the Hog Ranch we find that it has several long hills with very steep grades and sharp turns and for the greater part of the roadbed consists solely of the local surface materials, mostly earth, which makes a fairly smooth and hard road during the dry season, but which in wet weather and under heavy teaming would cut down into ruts and deep mud. The grades on the long hill at Woods Creek and at Priests Hill were found by actual measurement to average from 18 to 20 per cent for long stretches, and the long hills on both sides of the south fork crossing, as well as shorter hills at other places, are certainly as steep, if not steeper, than Priests Hill.

Obviously, to obtain economy in the transportation of the large quantities of machinery and supplies required for this work, a matter of early necessity will be a new road with lighter grades and harder roadbed, suitable for heavy freighting by teams or motor trucks; or for the operation of a temporary construction railway. In the latter case, on the completion of the work, the roadbed could be converted by slight widening and some surfacing, into an excellent highway for horse and automobile travel to the Hetch Hetchy region.

Thirteenth Division—New Construction Railroad

It is proposed to grade a new road about 62 miles long from Rosasco to Hetch Hetchy damsite, and to use it for a railroad during the construction period. The roadbed to be 15 feet wide, with adverse grades made as light as practicable against loaded trains going East, possibly not to exceed 3 per cent; and against empty trains going westward not to exceed 4 per cent.

To save expense, sharp curvature should be used freely, possibly up to curves of 30 degrees or 193 feet radius at the sharpest bends. This road will be located on the south slope of the Tuolumne Canyon for about 31 miles and the work will be generally of the character found on the steep slopes of the Sierras where the ordinary wagon roads are graded at an average cost of $3,000 or $4,000 per mile. There will be a few short sections where slopes are precipitous and the work will be very expensive.

A roadbed adaptable to the operation of a railroad will, of course, cost more per mile than an ordinary road.

The construction cost for grading this new road has been carefully considered by short sections and has been estimated as $572,000 for the 62 miles from Rosasco to Hetch Hetchy.

To this must be added the cost of the railroad which has been estimated as follows:

62 miles main line	@ $7,400	$458,800
2 miles sidings (9 in all)	@ $6,500	13,000
62 miles telegraph line		12,000
Warehouses, 2 @ $1,500; depots, 3 @ $1,000; section houses, 8 @ $500; tool houses, 10 @ $50, etc.		10,500
3 fuel and water stations		7,500
Repair shed and machine shop		10,000
Total cost of railroad, superstructure and buildings		$511,800

Ample equipment of locomotives and cars for construction purposes can be supplied for about $70,000 additional.

Total cost of construction railroad for grading, superstructure and rolling stock, but exclusive of headquarters, expenses for administration and engineering, also contractor's profit. . . . $1,154,200

Fourteenth Division—Scenic Road

To completely encircle the Hetch Hetchy Reservoir will require about 19 miles of road, and a suggested branch to the Tiltill Valley would be about 3 miles more. It is not presumed that this entire mileage will be built at once of the standard type of excellent road which it is hoped will be built eventually.

This estimate provides for 10 miles of good road, reaching from the dam to Wapama Falls, about 2½ miles; and for about 7½ miles on the south side of the valley from the dam to near the head of the reservoir; also the estimate provides for 10 miles of road of cheaper character on the north side of the reservoir.

A reconnaissance of this road location for the purpose of judging the probable cost was recently made by Mr. W. C. Hammatt, C. E. His report indicates that the grading will be generally heavy and for some portions very expensive. Using his notes as a basis it is estimated that 20 miles of roads as specified above can be built for $341,000.

Fifteenth Division—Irvington-Chabot

This division includes the branch aqueduct extending from the main aqueduct at the Irvington Gate House, Mile 20.6, to Lake Chabot at Mile 36.2, a distance of 15.6 miles; also the enlargement of the Lake Chabot dam and other structures necessary to raise the flow line of the reservoir to elevation 350. The miles as here stated refer to the distance from San Francisco City Hall. The distance from Oakland City Hall would be eight miles less.

The aqueduct consists of alternating sections of pressure tunnel, steel pipe siphons and probably some concrete pressure aqueduct.

The following is an estimate of the principal items of cost, starting from the Irvington Gate House. The cost of the new construction necessary for the enlargement of Lake Chabot has been taken from the estimate of Mr. George T. Prince, C. E. See page 134. Mr. Prince's figures presumably include the cost of administration, heavy plant and contractor's profit, and it has been necessary to modify his total by excluding the above named charges, in order to conform to the method used in my estimates.

ALTERNATIVE BRANCH AQUEDUCT TO LAKE CHABOT FROM IRVINGTON

(1) Tunnel 10 feet diameter—	
11,100 lineal feet in Santa Margarita sandstone @ $32	$355,200
4750 lin. feet in Monterey shale @ $32	152,000
(2) Siphon across Alameda Creek—	
Steel pipe 6.75 ft. diameter, average thickness 7-16 inch, maximum head 330 feet, 3700 lin. ft. @ $20	74,000
Embankment and piers for pipe bridge across creek, blowoffs, and manholes	20,000
2 portal cuts and pipe connections—	
4000 cubic yards, excavation @ 90c	3,600
440 lineal feet pipe tunnel @ $43	18,900
350 cubic yards concrete refill @ $7	2,500
(3) Two double compartment shafts—	
90 and 120 feet deep at Miles 34 and 35, respectively, 210 lin. ft. @ $100	21,000
(4) Tunnel 10 feet diameter—	
23,760 lineal feet in Knoxville shale and sandstone @ $33.50	796,000
11,100 lineal feet in Serpentine @ $38	421,800
7,920 lineal feet in Knoxville shale and sandstone @ $32	253,400
(5) Seven double compartment shafts, 270, 60, 40, 130, 180, 130 and 120 feet deep at Miles 31.9, 30.5, 30.0, 28.0, 26.8, 25.7 and 25.3 respectively, 930 ft. @ $100	93,000
(6) Siphon across San Lorenzo Creek—	
Steel pipe 6.75 feet diameter, average thickness ⅜ inch, maximum head about 240 feet, 5280 lin. ft. @ $17.50	92,400
Embankment and piers for pipe bridge across creek, blowoff and manholes	8,000
2 portal cuts and pipe connections—	
8000 cu. yds. excavation @ 80c	6,400
440 lineal feet, pipe tunnel @ $43	18,900
350 cu. yds. concrete refill @ $7	2,500
(7) Tunnel 10 feet diameter—	
4750 lineal feet in Serpentine @ $38	180,500
9,500 lineal feet, reinforced, in Serpentine @ $44	418,000
(8) Portal cut at Lake Chabot—	
12,000 cu. yds. @ 90c	10,800
(9) Enlargement of main dam and auxiliary works to increase storage capacity of	
Carried forward	$2,948,900
Brought forward	$2,948,900
Lake Chabot (Mr. Prince's estimate modified to exclude engineering and contractor's profit)	2,348,700
Construction cost of Lake Chabot Division, exclusive of general administration, heavy plant and contractor's profit	5,297,600

Sixteenth Division Poopenaut Dam

Eventually it will become desirable to utilize the storage of the Poopenaut Valley to conserve the surplus flood waters which will overflow from the Hetch Hetchy Reservoir. This is a very favorable site for a dam of considerable height for a comparatively small cost. The reservoir will be much smaller than the Hetch Hetchy but of sufficient size to make it well worthy of construction at some future time.

Two heights of dam have been considered for this place. The higher dam as shown by sketches on following pages is 235 feet high and would impound 17 billion gallons of water. The lower dam to be built as a first instalment of the high dam is assumed as 150 feet high.

Following is a summary of a rough estimate of cost of the Low Dam:

SUMMARY FOR A LOW POOPENAUT DAM.

(With spillcrest at elevation 3,460.)

Height, 150 feet between water levels. Length, 300 feet.

Clearing reservoir site, say, 100 acres @ $100	$10,000
Camp buildings, dwellings and offices	25,000
Construction roads	3,000
Camp maintenance and repairs	25,000
Temporary buildings for construction plant	23,000
Preparation of foundations, including preliminary work on future pressure tunnel	32,000
Water control during construction	16,000
Masonry in main dam and accessories, Portland cement concrete mainly made from gravel, 20% "plums" bedded in body of the large structures	312,700
Draw-off gates and accessories, and steel lining of conduits	40,000
Plant maintenance and repairs	35,000
Landscape architectural treatment near dam	4,000
Engineering, superintendence and contingencies	26,300
Construction cost of Low Poopenaut Dam, exclusive of administration, heavy plant and contractor's profit	$552,000

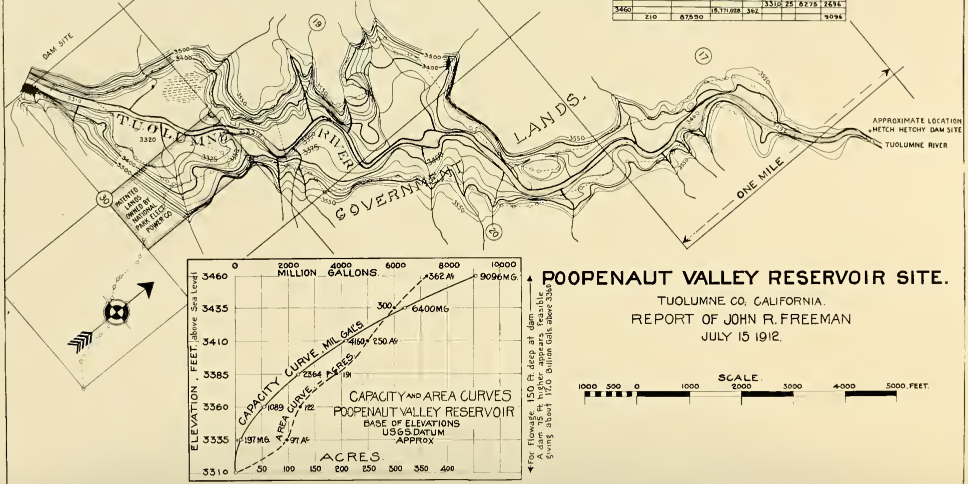
A still smaller and cheaper dam would probably serve all important purposes here for many years.

NOTE: CONTOURS ON THIS MAP WERE OBTAINED BY SUBTRACTING 140 FEET FROM ELEVATIONS GIVEN ON A MAP PREPARED UNDER THE DIRECTION OF MARSDEN MANSON, CITY ENGINEER OF SAN FRANCISCO, FROM SURVEYS MADE UNDER HIS DIRECTION IN 1911, SEPT. 1-7, BY H.W. SWANITZ, ASST. ENGR.

ESTIMATED CONTENTS OF POOPENAUT VALLEY RESERVOIR

Computed Nov 1911

Contour	Height of Dam above a plane 50' below low water	Contents of Dam Cu Yds.	Reservoir Area		Mean Area Acres	Mean Depth	Reservoir Capacity	
			Sq Ft	Acres			Acre Ft	Mil Gals
3310			0	0				
					485	12.5	606	197
3335			4,222,527	97				
					1095	25	2737	892
3360			5,309,378	122				
					1565	25	3913	1275
3385			8,299,227	191				
					2205	25	5512	1796
3410			10,907,992	250				
					2756	25	6875	2240
3435			13,084,112	300				
					3310	25	8275	2696
3460			15,771,028	362				
	210	87,590						9096

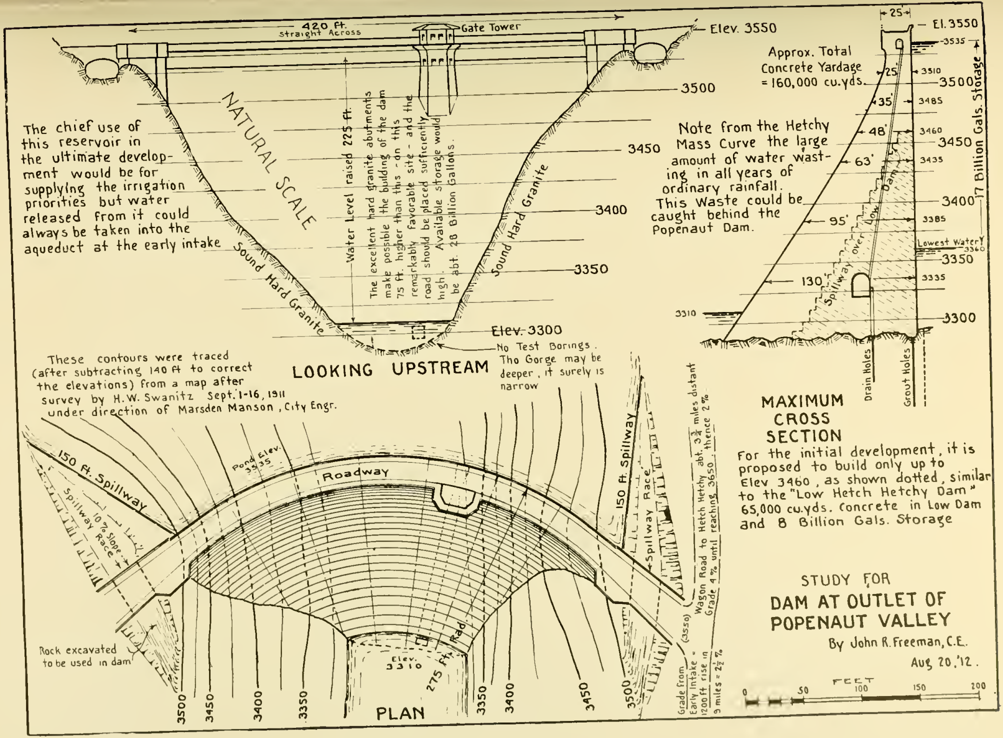


POOPENAUT VALLEY RESERVOIR SITE.

TUOLUMNE CO. CALIFORNIA.

REPORT OF JOHN R. FREEMAN

JULY 15 1912.



STUDY FOR
DAM AT OUTLET OF
POPENAUT VALLEY
By John R. Freeman, C.E.
Aug 20, '12.

420 ft. Straight Across
Gate Tower
Elev. 3550
3500
3450
3400
3350
Elev. 3300
NATURAL SCALE
Sound Hard Granite
Sound Hard Granite
Water Level raised 225 ft.
The excellent hard granite abutments make possible the building of the dam 75 ft. higher than this - on this remarkably favorable site - and the road should be placed sufficiently high. Available storage would be abt. 28 Billion Gallons.
The chief use of this reservoir in the ultimate development would be for supplying the irrigation priorities but water released from it could always be taken into the aqueduct at the early intake
No Test Borings. Tho Gorge may be deeper, it surely is narrow
LOOKING UPSTREAM
These contours were traced (after subtracting 140 ft to correct the elevations) from a map after survey by H.W. Swanitz Sept. 1-16, 1911 under direction of Marsden Manson, City Engr.
25
El. 3550
3535
Approx. Total Concrete Yardage = 160,000 cu.yds.
25'
3510
3500
35'
3485
48'
3460
3450
63'
3435
3400
95'
3385
17 Billion Gals. Storage
Lowest Water 3360
3350
130'
3335
3310
3300
Low Dam
Spillway over Low Dam
Note from the Hetchy Mass Curve the large amount of water wasting in all years of ordinary rainfall. This Waste could be caught behind the Popenaut Dam.
Drain Holes
Grout Holes
MAXIMUM CROSS SECTION
For the initial development, it is proposed to build only up to Elev 3460, as shown dotted, similar to the "Low Hetch Hetchy Dam" 65,000 cu.yds. Concrete in Low Dam and 8 Billion Gals. Storage
150 ft. Spillway
Spillway Race
10% Slope
Pond Elev. 3335
Roadway
150 ft. Spillway
Spillway Race
Wagon Road to Hetch Hetchy abt. 3¾ miles distant Grade 4% until reaching 3650, thence 2%
(3550)
Grade from Early Intake = 1200 ft rise in 9 miles = 2½%
Rock excavated to be used in dam
Elev. 3310
275 ft. Rad.
3500
3450
3400
3350
3350
3400
3450
3500
PLAN
FEET
0
50
100
150
200

ALTERNATIVE PROJECTS FOR DELIVERY OF HETCH HETCHY WATER FROM CRYSTAL SPRINGS RESERVOIR TO THE CITY.

For purposes of estimate and further study, three plans have been considered—(See Map "A", page 112.)

Tunnel Plan

This is the most perfect, but in comparison it appears unnecessarily expensive, and economy is important in view of the great cost of the enterprise as a whole.

1—A single aqueduct consisting as far as practicable of 10-foot diameter pressure tunnels, built to full size, with pipe connections across the valleys where tunnels are not feasible. Two lines of cement-lined pipe, 7.5 feet net diameter, are specified for these cross-valley connections between the tunnel portions of the aqueduct, one to be laid at the outset, and the other later when needed. Two 7.5-foot pipes, with the hydraulic gradient available, are capable of delivering much more than 200 million gallons daily, but with this liberal provision it will be possible to meet the daily fluctuations of draft, or to speedily refill depleted service reservoirs.

For this plan the tunnel intake from Crystal Springs lake is located about one mile northerly from the San Mateo dam. The floor of the tunnel at elevation 175 is low enough to draw Crystal Springs reservoir down 100 feet. It will be possible to get at least six miles of pressure tunnel in the Buriburi ridge. The proposed tunnel location runs nearly parallel with San Andreas lake for one and one-half miles. A connection can be made by means of pumps and a short branch tunnel to that reservoir, with its flow line at 125 feet higher elevation than the Crystal Springs reservoir after the dam at the latter place has been raised to its final elevation.

This junction point and pumping station can be conveniently located about one and one-half miles westerly from Millbrae. A suitable arrangement of connections and gates at this junction beside providing for feeding the water into the reservoir, will also permit of drawing it back into the main aqueduct, or some other conduit, to continue its course by gravity to portions of the city at higher levels than can be supplied directly from the Crystal Springs reservoir. This San Andreas lake connection will make the existing pipe lines of the Spring Valley Water Company's San Andreas system available for the delivery of Hetch Hetchy water to Lakes Merced and Honda, and to the College Hill and Lombard street reservoirs.

From the north end of the Buriburi tunnel there will be about 3.9 miles of 7½-foot pipe across the valley to San Bruno mountain, where there is another pressure tunnel 3.3 miles long extending to the Islais Creek valley. In this vicinity a junction can be made with the city's distribution mains permitting direct delivery of water into the same, also to the low-service reservoirs at College Hill and University Mound, or by continuation of the main aqueduct by pipe line and a short pressure tunnel it can be delivered into the proposed San Miguel reservoir.

Steel Pipe Line via Crystal Springs Reservoir

2—A single line of 4.5-foot pipe, with or without cement lining, from Crystal Springs dam to University Mound reservoir. This pipe would have with uniform flow, a daily capacity of about 60 million gallons and would be laid as soon as it might become necessary to supplement the capacity of the Spring Valley Water Company's existing 44-inch main from Crystal Springs reservoir to University Mound and its other city connections.

Starting at the Crystal Springs the first pipe to be laid would follow the canyon of San Mateo creek to its mouth and thence in a fairly direct line over the slightly undulating ground near the base of the hills to Millbrae, where connection could be made with the pumps for the delivery of water into the San Andreas reservoir and other branches of the Spring Valley Water Company's system. From Millbrae the pipe would be buried in the highway passing thru San Bruno and the westerly portion of South San Francisco, to the San Bruno mountains; thence to University Mound the conduit would run thru mountainous country, requiring three tunnels alternating with pipe siphons across Guadalupe and Visitacion Valleys.

Because of the various possibilities presented at the Millbrae pumping station for modification or temporary postponement of construction on either of the above described aqueducts, this section from Crystal Springs to San Miguel has been subdivided into two divisions for each of the alternate propositions.

Steel Pipe Line Direct from Redwood Gate House

3—In this alternative which appears on the whole most advantageous in delivering the soft pure mountain water direct from the aqueduct, without exposure in reservoirs or admixture with other water, and most economical because of substituting a 4.5 ft. steel pipe for the tunnel into Crystal Springs reservoir and the future by-pass along the reservoir margin, the cement lined steel pipe 6.5 ft. diameter across the bay terminates in a manifold and gate house near Redwood City, whence one branch of steel pipe 4.5 ft. diameter runs into San Francisco and another into Crystal Springs Reservoir. The cost of this is estimated elsewhere.

First Division, San Miguel-Millbrae

(A) *Tunnel Aqueduct*, capacity 200 million gallons daily.

The work comprised in this division extends from the gate house at the proposed San Miguel Reservoir to the gate house and pumping station at Millbrae junction of the branch line to San Andreas Reservoir. Distance 9.70 miles. The principal items of cost taken in their order from San Miguel Reservoir will be—

1—Pipe line from San Miguel Dam to tunnel connection at Mile 4.3. Laid in trench mainly along valley floor. Easy digging.	
1,620 lin. ft. 4.5-foot steel pipe, ¼ inch thick, weight 158 lbs. per foot, at $7.50 . .	$12,150
2—Portal cuts and pipe connections at short pressure tunnel. Only one pipe will be laid at first, but provision will be made at tunnel ends for two pipes. This will require a wider section of tunnel into which the pipes will be inserted, and a concrete chamber or bell-mouth at their junction with the pressure tunnel. The pipe tunnel to be refilled with concrete around the pipes to make water-tight closure at ends of pressure tunnel.	
2.400 cu. yds. hard rock excavation in open cut, at $1.25	3,000
500 cu. yds. earth excavation, at 30c	150
100 lin. ft. pipe tunnel, 14 ft. x 6 ft., excavation only, at $19 per foot	1,900
130 cu. yds. concrete refill, at $8	1,040
3—800 lin. ft. 6-ft. pressure tunnel thru hard rock, at $20.25	16,200
4—Pipe line across Islais Creek Valley. Completely buried for 80 per cent of length; passes under two railroads; 8-ft. arch culvert at Islais Creek. Easy digging.	
4,800 lin. ft. 4.5-foot pipe, ¼ inch thick, weight 158 lbs. per foot, at $8	38,400
5—Junction valve chamber and small gate house for connections to city distribution mains, and to San Miguel Reservoir.	
Substructure, 26 ft. x 28 ft.	
160 cu. yds. concrete, at $15	2,400
540 cu. yds. excavation, at $1	540
Superstructure of brick or stone	2,800
Special fittings, valves and operating devices	9,000
6—Steel pipe from junction gate house to north-end of pressure tunnel, thru San Bruno Mountain. To make safe against high pressure in San Bruno Tunnel, pipe must enter tunnel about 1,600 ft. and two lines of pipe with concrete refill will be required for 120 feet.	
2,500 lin. ft. 7.5-foot pipe, ¼ inch thick, weight 280 lbs. per foot, at $13	32,500
7—North portal cut and pipe connection for San Bruno Tunnel. Mountain slope is quite flat, making cut 800 ft. long.	
4,500 cu. yds. earth excavation, at 30c.	1,350
17,300 cu. yds. hard rock excavation, at $1	17,300
Special section of pipe tunnel, 22 ft. x 10 ft.; no lining; 70% timbered. 1,600 lin. ft. excavation, at $52.50	84,000
350 cu. yds. concrete refill, at $7	2,450
8—San Bruno Tunnel, 3.25 miles, thru sandstone and other hard rocks of the Franciscan formation; 60% timbered; dry; deep shaft and long haul.	
17,160 lin. ft. 10-foot tunnel, concrete lined for full length, at $35	600,600
9—Double compartment shaft, 12ft. x 18 ft., timbered full depth.	
320 lin. ft., at $125	40,000
10—South portal cut and pipe connection for San Bruno Tunnel. Cut about 500 feet long.	
2,200 cu. yds. earth excavation, at 30c . . .	660
8,900 cu. yds hard rock excavation, at $1 .	8,900
Special section of pipe tunnel, 22 ft. x 10 ft.; no lining; 70% timbered, 1,050 lin. ft. excavation, at $52.50	55,100
350 cu. yds. concrete refill, at $7	2,450
11—4.2 miles 7.5-foot steel pipe across valley between San Bruno and Buriburi Mountains. Three railroad crossings and seven stream beds of from 10 to 30 feet span, classified as follows:	
2,100 lin. ft. ¼-inch pipe, at $13	27,300
4,000 lin. ft. ⅜-inch pipe (average head 240 ft.), at $17	68,000
3,200 lin. ft. 15/32-inch pipe (average head 310 ft.), at $20	64,000
7,700 lin. ft. 9/16-inch pipe (average head 350 ft.), at $21.50	165,550
5,300 lin. ft. ⅝-inch pipe (average head 390 ft.), at $23	121,900
Allowance for additional excavation and embankment on rolling ground, 7,500 lin. ft., at $3.50	26,250
Allow for bridges, manholes, blow-off and miscellaneous	15,700

12—North portal cut and pipe connections for Buriburi Tunnel estimate for three open cuts with a short pipe tunnel intervening. Material all a fine compact silty sand. Open cuts say altogether 1500 ft. long.	
30,000 cu. yds. sand excavation, at 15c	4,500
Special section of pipe tunnel 22 ft. x 10 ft. lined, part thru rock and part thru sand. Sand portion can be best handled by the shield method and cost assumed as double that of 10-foot lined pressure tunnel thru sand.	
1,850 lin ft. thru sand, at $52	96,200
1,550 lin. ft. in hard rock, at $52.50	81,400
700 cu. yds. concrete refill, at $7	4,900
13—Buriburi Tunnel to gate chamber at San Andreas Junction; 0.5 mile thru hard rocks of Franciscan group; 70% timbered; little water.	
2,650 lin. ft. 10-foot tunnel, all concrete lined, at $36	95,400
Construction cost of the San Miguel-Millbrae Division "Tunnel Aqueduct", exclusive of charges for general administration, heavy plant and contractor's profit	1,704,000

(B) *Alternative Pipe Line*, capacity 50 to 60 million gallons daily.

The work comprised in this first division extends from a connection with the city main at the southwest corner of University Mound Reservoir to the existing pumping station at Millbrae, distance 9.25 miles.

The principal items of work taken in their order from the reservoir will be—

1—Valve chamber and connections with city mains and service reservoir at University Mound.	
300 cu. yds. excavation, at $1	$ 300
Three 48-inch gate valves and operating devices	8,000
Valve chamber and connections	2,000
2—Steel pipe to north end of Potrero Tunnel, 1,100 lin. ft. 4.5-ft. pipe ¼ inch thick, weight 158 lbs. per foot, at $7.50	8,250
Piers for stream crossing	1,500
3—Portal cuts and pipe connections at both ends of Potrero Tunnel. Provision to be made at tunnel ends for two pipes which requires a wider section of tunnel for a short distance.	
500 cu. yds. earth excavation, at 30c	150
2,400 cu. yds. hard rock excavation, at $1.25	3,000
60 lin. ft. pipe tunnel 14 ft. x 6 ft., at $19	1,140
100 cu. yds. concrete refill, at $8	800
4—Potrero Tunnel, thru hard rocks of the Franciscan formation; 50% timbered.	
3,200 lin. ft. 6-foot tunnel, concrete lined, at $20.50	65,600
5—Steel pipe across Visitacion Valley, one stream crossing.	
5,600 lin. ft. 4.5-foot pipe, ¼ inch thick, weight 158 lbs. per foot, at $7.50	42,000
Piers for stream crossing	1,500
6—Portal cuts and pipe connections at both ends of Guadalupe Tunnel, same as for Item 3	5,090
7—Guadalupe Tunnel thru hard rock, 50% timbered.	
2,400 lin. ft. 6-foot tunnel, concrete lined, at $20.50	49,200
8—Steel pipe across Guadalupe Valley, some heavy grading and one stream crossing.	
2,700 lin. ft. 4.5-foot pipe, ¼ inch thick, weight 158 lbs. per foot, at $7.50	20,250
Allowance for additional grading	3,500
Piers for stream crossing	1,500
9—Portal cuts and pipe connections at San Bruno Tunnel same as Item 3	5,090
10—San Bruno Tunnel thru hard rock, 50% timbered.	
5,800 lin. ft. 6-foot tunnel, concrete lined, at $20.50	118,900
11—Steel pipe to Millbrae Pumping Station, follows highway for about 4.6 miles, and crosses tidal flat for 0.7 miles. Seven stream crossings, some extra grading.	
28,300 lin. ft. 4.5-foot pipe, ¼ inch thick, at $7.50 per foot	212,250
Allowance for additional grading:	
3,200 lin. ft. embankment over marsh, at $1.10	3,520
5,000 lin. ft. San Bruno slopes, at $2	10,000
20,100 lin. ft. in trench in highway, at 60c.	12,060
Piers for 7 stream crossings	10,500
12—3 blow-offs, manholes and miscellaneous	3,500

Construction cost of the San Miguel-Millbrae Division "Alternative Pipe Line", exclusive of charges for general administration, heavy plant and contractor's profit $589,600

Second Division—Millbrae-San Mateo

(A) *Tunnel Aqueduct*, capacity 230 million gallons daily.

This division comprises work extending from San Andreas Junction to Crystal Springs Intake, about 1 mile northerly from San Mateo Dam, or from Mile 14.2 to Mile 19.3, a distance of 5.1 miles, together with branch line, 0.4 miles long, to San Andreas Reservoir. Total distance 5.5 miles.

(1) *Gate Chamber* San Andreas Junction, Mile 14.2, shaft 180 feet deep, cost of which is included in other shafts.	
Gate chambers, connections, gates and pumping plant	$80,000
(2) *Main Tunnel*—	
26,900 lin. ft. of 10 ft. tunnel. 70% timbered ....@ $36	$968,400
(3) *Gate chamber and controlling gates* at Crystal Springs Intake............	30,000
(4) *Open channel connection* to Crystal Springs deep water—	
1,200 cu. yd. earth excavation..@ 60c	700
10,800 cu. yds. loose rock exacation... .... @ $1.50	16,200
(5) *Branch Tunnels.* 0.4 mile to San Andreas Reservoir, 0.25 mile long at Crystal Springs Reservoir.	
2,100 lin. ft. of 6 ft. tunnel....@ $20	42,000
1,300 lin. ft. of 10 ft. tunnel...@ $38	49,400
(6) *Open channel connection* with San Andreas.	
1,100 cu. yds. earth excavation..@ 60c	700
10,100 cu. yds. loose rock excavation.. .... @ $1.50	15,200
(7) Six double compartment shafts, severally 180, 200, 230, 180, 230 and 100 ft. deep, located at Miles 14.2, 15.3, 76.0, 16.7, 17.2, 19.3 respectively.	
1,120 lin. ft. of shafts......@ $100	112,000

Total construction cost for Millbrae-San Mateo Division (tunnel aqueduct), exclusive of charges for general administration, heavy plant and contractor's profit $1,314,600

(B) *Alternative Pipe Line.* Capacity 50 to 60 million gallons daily.

This division comprises work extending from the existing pumping station at Millbrae, Mile 14.0 to Crystal Springs Intake at San Mateo Dam, Mile 20.5, distance 6.5 miles.

(1) Steel pipe to San Mateo Dam.	
34,300 lin. ft. of 4.5 ft. steel pipe ¼ in. thick, weight 158 lbs. per foot..@ $8	$274,400
(2) Piers at 15 stream crossings and foundation work	15,000
(3) Allowance for additional grading.	
2,600 lin. ft. in trench in existing roads ....@ 60c	1,600
18,500 lin. ft. in trench over undulating land ....@ $1.50	27,800
13,200 lin. ft. in trench on San Mateo Canyon slopes ....@ $2.00	26,400
(4) Blow off, manholes, and miscellaneous......	3,000
(5) Pipe connections and additional pumps at Millbrae	300,000
(6) Gate house tower and controlling gates at San Mateo Dam	30,000

Total construction cost for Millbrae-San Mateo Division (pipe line), exclusive of charges for general administration, heavy plant and contractor's profit..........$678,200

Summarizing the totals of the estimates for the first and second divisions to get a comparison of the cost of the pressure tunnel aqueduct of full capacity, with the cost of an alternative scheme of development by using mostly a steel pipe of much smaller capacity than the tunnel and progressively adding more capacity by laying other pipes as demanded.

	Tunnel Aqueduct 230 M.G.D.	Pipe Line 50-60 M.G.D.
Division 1............	$1,704,000	$589,600
Division 2............	1,314,600	678,200
	$3,018,600	$1,267,800

The above shows an immediate saving in cost by using pipe instead of tunnel, of $1,751,000.

Crystal Springs By-pass. Cut and cover aqueduct.

This division comprises cut and cover aqueduct work extending from Crystal Springs Gate House, Mile 19.3, about one mile northerly from San Mateo Dam, to terminal Gate House, Mile 25.5, at south end of Crystal Springs Reservoir. Distance 6.2 miles.

(1) By-pass Aqueduct, 10 ft. diameter.	
Earth excavation, 127,100 cu. yds. @ 40c	$50,800
Rock excavation, 44,600 cu. yds. @ $1.50	66,900
Concrete, 49,900 cu. yds...... @ $7.00	349,300
Backfill, 144,500 cu. yds....... @ 30c	43,400
Trimming slopes, cleaning up, etc., 32,740 lin. ft. at $1.00..................	33,000
Add for excess of embankment over average as shown on typical section, say 16,500 lin. ft............. @ $4.00	66,000
(2) Add for culverts at 20 waterways, including excavation and masonry............	45,000
(3) Add for manholes, also sluice gates at tunnel ends	6,000
(4) Gaging chamber	4,700
Total construction cost for Crystal Springs by-pass—exclusive of charges for general administration, heavy plant and contractor's profit	$665,000

Allowance for Overhead Charges

In the following tabulation an attempt has been made to make fairly liberal additions to the field or construction cost of the works to cover items of expense which up to this tiem have been purposely omitted from the estimates presented in detail on preceding pages, but which must be included to get the final cost of the project.

Item 2. *Depreciation on Heavy Plant.*—Based on the assumption that the salvage value of same at the completion of the work will average about 40 per cent of the first cost. Each division has been considered as having to be supplied with all necessary machines, track and rolling stock to fully equip each working point, as if the work would be progressing contemporaneously on all the divisions and at every working point on each division.

The possibility of the plant being moved from one division to another and making it do service two or three times over has been disregarded because this consideration is of little consequence in tunnel work, since not much of the plant in use at any shaft or portal can ever be released before the work is substantially completed. Each shaft has therefore been charged with an equipment suited to the depth of the shaft and the length of the tunnel drifts.

The cost of the tunnel plant for each working point has been approximated from the following units estimated for three different cases:

Plant for one shaft and two drifts each ½ mile long.	$39,000
Plant for one shaft and two drifts each 1 mile long.	60,000
Plant for one shaft and two drifts each 2 miles long	96,000

As a charge for the special plant required for the long pipe lines has already been included in the unit costs of pipe, the additional allowance for those portions of the aqueduct have been comparatively small and apply only to excavating and concrete machinery; and derricks, pumps, etc., for minor structures at water ways. For this surface work the plant is regarded as movable from one point to another as the work progresses.

The floating equipment such as dredgers, tugs, piledrivers, scows, etc., required for the Bay Head and San Joaquin River crossings has been regarded as rented and is figured into the special estimates for extra work at those places.

Item 3.—*Construction of Roads and Trails:* This applies to local work such as roads about camp and short construction roads to shafts, quarries, sand and gravel pits, etc., and does not include any part of the cost of the main construction road from Rosasco to Hetch Hetchy dam site, or the Scenic Roads near the Hetch Hetchy Reservoir, which have been estimated separately.

Item 4.—*Transportation of Laborers:* This item of expense will depend on the remoteness of the work from San Francisco, also on the labor supply. If labor has to be imported from distant places, the cost may become a very important item.

Item 5.—*Contractor's Bond and Liability Insurance:* The contractor is usually required to give bond of from 10 to 20 per cent of the total amount of his contract to insure the faithful performance of his work. The premium charged by bonding companies is usually one per cent per annum on the amount of the bond. For a contract extending over two years, this would amount to from one-fifth to two-fifths of one per cent of the construction cost of the work. The rates for employer's liability insurance are based on the amount of the payroll and vary according to the character of the work. The rate is less for men engaged in ordinary labor on the surface of the ground than for those in the more hazardous occupation of tunnelling. The minimum rate on the Pacific Coast for laborers subjected only to common hazard is one-half of one per cent of the amount of the payroll for that class of labor.

The allowance in this estimate of one per cent of the construction cost of the work would seem to be more than enough to cover the actual charges for bonds and liability insurance.

Item 6.—*Contractor's Profit:* Contractors generally figure on a profit of from 10 to 20 per cent of the cost of the work to them, according to the size of the contract, and the length of time required for its performance. Where the contract involves the purchase of large quantities of material manufactured by other parties it is proper to reduce correspondingly the percentage of profit, allowing the contractor only a commission for acting as purchasing agent. In these estimates 15 per cent has been added for regular profit in all cases except Divisions 4, 6 and 8, where account has been taken of the great quantity of steel entering into the long pipes of large diameter. For these three divisions the percentage of profit has been figured on the basis of 3 per cent profit on the cost of steel delivered at tidewater, and 15 per cent profit on the remainder of the work.

Item 8.—*Administration, Legal Services, and Headquarters Engineering:* It is assumed that the general management will be assigned to a Water Board appointed by the Bay Cities and to be given full authority over the matters concerning the construction of the Hetch Hetchy project, thereby following the method which has given the most satisfactory results in cities where water works construction has been carried out on a large scale. This Board should have an engineering organization of its own, independent of the City Engineer. The work of the engineering department naturally divides itself into two classes,—

(a) The executive and designing work of the central office, including general surveys, lines of bench levels and other preliminary work.

(b) The field work of giving lines and grades, making measurements of quantities for estimates, keeping account of costs and maintaining proper supervision and inspection.

The cost of the field engineering (b) has been included in the construction cost, thus leaving only the headquarters engineering to be accounted for at this time.

In the effort to obtain data upon administration and headquarters cost from similar large enterprises we note the following:

From statements of cost in the Annual Report of the Board of Water Supply for the City of New York for the year 1910, the headquarters and administration expenses appear to have been as follows:

In percentage of entire cost.

Administration	0.75%
Legal services and land condemnation	2.58%
Headquarters engineering	2.00%
Field	6.28%

The work was apparently only about one-half completed at the date of the report. While the designing was largely completed, on the other hand the above percentages refer to total cost, instead of construction cost, which lessens the figures.

From the Sixth Annual Report of the Los Angeles Aqueduct Commission we deduce from costs given up to June 30, 1911.

	Per Cent of Entire Cost	Per Cent of Construction Cost
Administration and engineering	2.6	2.8
Legal expenses	0.31	0.33
Field engineering	2.0	2.3

Remembering that Field Engineering has already been included in our construction costs on the basis of the Los Angeles work, and omitting that item from the totals given below, we have for

New York—Administration, Headquarters engineering and legal services	5.33 per cent
Los Angeles—Administration, Headquarters engineering and legal services	2.91 per cent

The cost of condemnation proceedings in New York is generally considered excessive. In view of the fact that in neither case above was the work finished and that these expenses largely precede the construction, an allowance of 3½ per cent has been assumed as a fair one to be made in this estimate.

It must be remembered that the above estimate for engineering is for headquarters engineering only, and that there must be an addition of 7 to 9 per cent of the construction cost for field engineering and inspection if the work is done by contract.

OVERHEAD COSTS ON DIVISIONS OF HETCH HETCHY PROJECT

BY DIVISIONS GROUPED IN ORDER OF THEIR IMPORTANCE WITH RELATION TO THE DEVELOPMENT OF THE TUOLUMNE SUPPLY PRIMARILY FOR SAN FRANCISCO, AND SECONDARILY FOR THE OTHER BAY CITIES WHEN DESIRED.

Note that some of these items pertain to Oakland, Berkeley, Alameda and other communities and that some may be deferred many years.

The proposed structures have been designed with a view to an ultimate supply of 400 to 500 mil. gals. daily to San Francisco and the bay cities, but for the initial development the works will only have a capacity of 240 mil. gals daily delivered to Irvington Gate House, and thence to Crystal Springs and Lake Chabot, of not less than 100 mil. gals. daily for each branch. All the tunnels and permanent masonry structures (except dams) are to be built full size at the start, but the immediate capacity of the long pipe lines will be only sufficient to take care of the first development. This statement shows the estimated field construction cost of each division and the additional allowances for overhead charges to obtain a total sufficient to cover the entire cost of the work from start to finish.	MAIN AQUEDUCT.						Hetch Hetchy Dam and Reservoir.	Eleanor-Cherry. Tunnel and Dams.
	Division 4. Crystal—Irvington. Length 22.4 Miles. (Cheaper plan possible.)	Division 5. Irvington—Calaveras. Length 3.25 Miles. See Foot Note (a).	Division 6. Calaveras—Antonio. Length 1.95 Miles. See Foot Note (b).	Division 7. Antonio—Valle. Length 6.85 Miles.	Division 8. Valle—Moccasin. Length 80.6 Miles. See Foot Note (c).	Division 9. Moccasin—Early Intake. Length 19.5 Miles.	Division 11. Hetch Hetchy. Low Dam to Elevation 3670.	Division 12. Eleanor—Cherry. Two Dams and Reservoirs and Tunnel. Length 6.8 Miles. (May be deferred.)
(1) Total Construction Cost, exclusive of general administration, heavy plant, contractor's profit and other items specified below	$2,684,000	$836,300	$339,000	$1,854,000	$15,391,400	$3,856,800	$725,800	$1,656,000
(2) Add for heavy plant—net cost after probable 40% salvage on compressors, hoists, drills, pumps, crushers, concrete mixers, miscellaneous machinery, rails, rolling stock etc.	93,000	76,800	31,800	120,000	625,200	328,200	163,800	103,800
(3) Cost of local construction roads and trails	16,400	1,000	3,000	7,000	40,000	12,000	....	50,000
(4) Transportation of laborers. . .	5,000	1,500	2,000	3,500	30,000	10,000	3,000	3,500
(5) Contractor's bond and liability insurance 1% of Item 1. . .	27,000	8,400	3,400	18,500	154,000	38,600	7,300	16,600
(6) Total	$2,825,400	$924,000	$379,200	$2,003,000	$16,240,600	$4,245,600	$899,900	$1,829,900
(7) Add for contractor's profit 15% of Item 6, except for Divisions 4, 6 adn 8, where the percentage has been reduced because of the large quantity of purchased material entering into the long pipe lines. The percentage noted for each case represents 3% on the cost of steel and 15% on the remainder of the amount of Item 6. . .	11% 309,000	138,600	14% 52,000	300,000	12% 1.999,000	636,800	135,000	274,500
(8) Add for administration, legal services, headquarters, engineering (designing), etc., 3½% of Item 6. See foot note (e)	99,000	32,300	13,300	70,000	568,000	148,500	31,500	64,000
(9) Add for water rights, lands and easements for right of way	167,600	6,000	4,800	8,000	215,700	31,700	*166,000	*1,070,000
(10) Total	$3,401,000	$1,100,900	$449,300	$2,381,000	$19,023,300	$5,062,600	$1,232,400	$3,238,400
(11) Add for interest on expenditures during construction, 4½% for 3 years on one-half of the total cost, or 13½% of one-half of Item 10	229,400	74,200	30,300	160,500	1,283,000	341,000	83,100	218,000
(12) TOTAL, being the ENTIRE COST of the fully completed work	$3,630,400	$1,175,100	$479,600	$2,541,500	$20,306,300	$5,403,600	$1,315,500	$3,456,400

(a) $42,200 deducted for Calaveras Branch not essential to Hetch Hetchy project.

(b) $743.600 deducted for San Antonio Reservoir and branch tunnel and gate house not essential to Hetch Hetchy project.

(c) $59,800 deducted for grading road from Rosasco to Tuolumne River at Red Mountain Bar and for highway bridge across river. This cost is now included as a part of the cost of the construction railroad, Division 13.

(d) The length of the scenic roads is optional from 22 to 15 miles, or even less. Ten miles of first-class road and ten miles of cheaper road have been provided for in the above estimate.

OVERHEAD COSTS ON DIVISIONS OF HETCH HETCHY PROJECT

BY DIVISIONS GROUPED IN ORDER OF THEIR IMPORTANCE WITH RELATION TO THE DEVELOPMENT OF THE TUOLUMNE SUPPLY PRIMARILY FOR SAN FRANCISCO, AND SECONDARILY FOR THE OTHER BAY CITIES WHEN DESIRED.

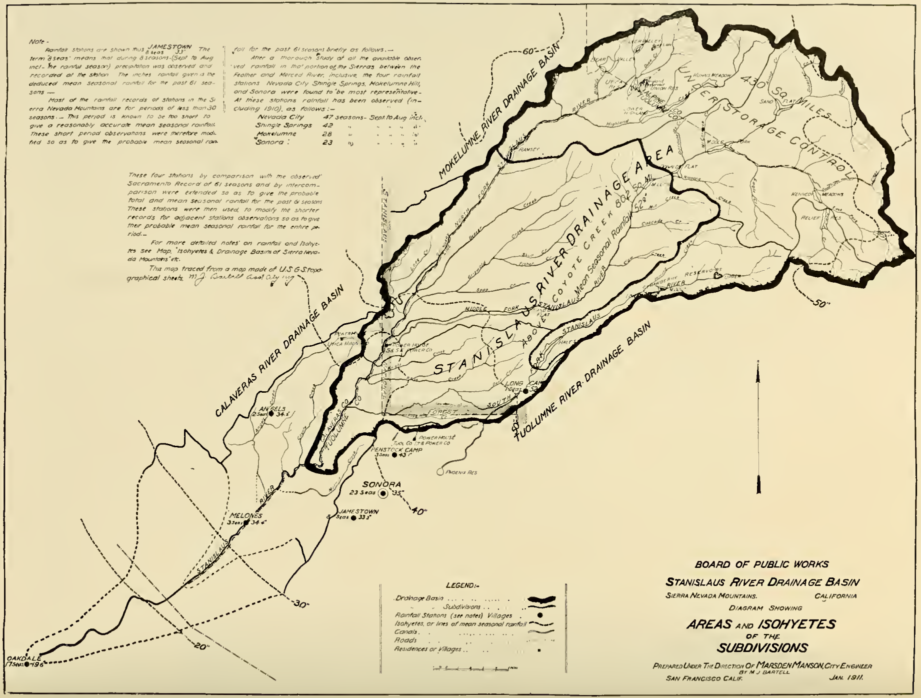
(Note that some of these are alternatives of which only one would be used, and that some of this work may be deferred many years.)

		San Francisco—Crystal Springs Connection.				Lake Chabot Development.				
Construction Road.	Scenic Roads.	Tunnel.	Alternative Pipe.	Tunnel.	Alternative Pipe.	Aqueduct.	Reservoir.	Crystal Springs By-Pass.	Poopenaut	Main Aqueduct.
Division 13. Construction Road, with Temporary Railroad. Length 62 Miles.	Division 14. Scenic Roads at Hetch Hetchy and Tiltill Valleys. Length 20 Miles. See Foot Note (d).	Division 1. San Miguel—Millbrae. Length 9.75 Miles.	Division 1. University Mound to Pumping Station at Millbrae. Length 9.25 Miles.	Division 2. Millbrae—San Mateo. Length 5.40 Miles.	Division 2. Millbrae—San Mateo. Length 6.5 Miles.	Division 15. Irvington—Chabot. Length 15.55 Miles.	Division 17. Main Dam and Dike for Raising Lake Chabot to Flow Line at Elevation 350.	Division 3. Crystal Springs Reservoir By-Pass. Length 6.20 Miles.	Division 16. Poopenaut Dam and Reservoir for Low Dam to Elevation 3460.	Division 10. Canyon. Length 12.10 Miles.
$572,000	$341,000	$1,704,000	$589,600	$1,314,600	$678,200	$2,948,900	$2,348,700	$665,000	$552,000	$2,382,300
417,800	5,000	91,200	49,800	124,800	4,800	295,000	80,000	36,000	150,000	274,800
....	.....	28,000	6,500	8,000	6,000	39,500	1,000	7,500	.....	23,000
6,000	2,000	1,000	500	1,500	1,000	4,000	1,000	1,000	2,500	6,000
5,700	3,400	17,000	5,900	13,100	6,800	29,500	23,500	6,600	5,500	23,800
$1,001,500	$351,400	$1,841,200	$652,300	$1,462,000	$696,800	$3,316,900	$2,454,200	$716,100	$710,000	$2,709,900
150,200	52,700	276,000	97,800	219,300	104,500	497,500	368,000	107,400	106,500	406,500
35,000	12,300	64,400	22,800	51,100	24,400	116,000	85,800	25,000	24,800	94,800
20,000	......	221,000	86,000	13,200	30,000	93,000	100,000	13,200	......	1,000
$1,206,700	$416,400	$2,402,600	$858,900	$1,745,600	$855,700	$4,023,400	$3,008,000	$861,700	$841,300	$3,212,200
81,400	28,100	162,000	57,900	117,500	57,700	271,000	203,000	58,100	56,800	216,500
$1,288,100	$444,500	$2,564,600	$916,800	$1,863,100	$913,400	$4,294,400	$3,211,000	$919,800	$898,100	$3,428,700

(e) This applies solely to the headquarters expense. The cost for field engineering on the basis of Los Angeles amounts to 2¼% additional. This latter amount has been charged into the construction cost (Item 1) for each division.

On the new Catskill Aqueduct for the City of New York, and on the aqueducts recently built for the Boston Metropolitan District, where the work was mostly done by contract, the additional cost of field engineering and inspection apparently averages as much as 7% or even 8% of the cost of the entire work.

*Includes cost of land and water rights for Hetch Hetchy, Eleanor and Cherry.



Note -

Rainfall stations are shown thus $\underset{8\text{ seas}\quad 33"}{\text{JAMESTOWN}}$ The term "8 seas" means that during 8 seasons (Sept to Aug incl.- the rainfall season) precipitation was observed and recorded at the station. The inches rainfall given is the deduced mean seasonal rainfall for the past 61 seasons —

Most of the rainfall records of stations in the Sierra Nevada Mountains are for periods of less than 30 seasons.— This period is known to be too short to give a reasonably accurate mean seasonal rainfall. These short period observations were therefore modified so as to give the probable mean seasonal rainfall for the past 61 seasons briefly as follows.—

After a thorough study of all the available observed rainfall in that portion of the Sierras between the Feather and Merced River, inclusive, the four rainfall stations Nevada City Shingle Springs, Mokelumne Hill, and Sonora were found to be most representative.- At these stations rainfall has been observed (including 1910), as follows:—

Nevada City	47	seasons-	Sept. to Aug incl.
Shingle Springs	42	"	" " " "
Mokelumne	28	"	" " " "
Sonora :	23	"	" " " "

These four stations by comparison with the observed Sacramento Record of 61 seasons and by intercomparison were extended so as to give the probable total and mean seasonal rainfall for the past 61 seasons. These stations were then used, to modify the shorter records for adjacent stations observations so as to give their probable mean seasonal rainfall for the entire period.—

For more detailed notes on rainfall and Isohyetes see Map, "Isohyetes & Drainage Basins of Sierra Nevada Mountains" etc.

This map traced from a map made of U.S.G.S. topographical sheets. M. J. Bartell Asst City Eng

BOARD OF PUBLIC WORKS
STANISLAUS RIVER DRAINAGE BASIN
SIERRA NEVADA MOUNTAINS. CALIFORNIA
DIAGRAM SHOWING
AREAS AND ISOHYETES
OF THE
SUBDIVISIONS
PREPARED UNDER THE DIRECTION OF MARSDEN MANSON, CITY ENGINEER
BY M J BARTELL
SAN FRANCISCO CALIF. JAN. 1911.

Appendix No. 10

STANISLAUS RIVER PROJECT AND COST ESTIMATE

By C. E. Grunsky, Consulting Engineer.
July 31, 1912.

(Abstract of report filed in triplicate with Advisory Board of Army Engineers on August 1, 1912, Revised August 20.)

The Stanislaus River as a source of water for San Francisco deserves consideration only because of its location just north of the Tuolumne River. This is, therefore, a source of supply which though inadequate as an independent source might conceivably be available for supplementing a supply from Lake Eleanor and the adjacent region.

This river was reported on as an independent source of supply by the writer, at that time City Engineer, in 1901. (See Municipal Reports 1900-01, Appendix, pages 344 to 347.) The South San Joaquin and Oakdale irrigation districts are now engaged in the construction of a diverting dam and irrigation canal of large capacity for irrigating about 143,000 acres, which makes water from this source even less available for San Francisco than formerly.

Catchment Area

The Stanislaus River has a drainage basin above Knights Ferry of about 935 square miles, but the area under possible storage control is very much less, as will be seen by the map, and the possible reservoir sites are scattered on the headwaters where tributary areas are small and they make poor regulators for the river as a whole. It is one of the smaller of the large streams that drain the western slope of the Sierra Nevada. The lower portions of its watershed have the usual characteristics of the Sierra Nevada foothills region, being fairly well covered with foothill oak, pine and scrub growths up to elevations of about 3,000 feet. Above this elevation particularly on northern exposures are coniferous forests largely in private ownership.

Possible Sources of Pollution

Mining and the cutting of lumber, also farming in the small valleys which abound in the foothills, have brought into the lower part of the watershed a considerable population. Murphys, Angels Camp and Vallecito are among the small centers of population.

In the higher mountains there are some sources of possible pollution such as the lumber camps and occasional summer resorts such as Strawberry on the South Fork and here and there the headquarters of cattlemen, but nearly all of the high mountain area tributary to this river is in the Stanislaus National Forest Reservation.

No Sites for Large Storage Reservoirs

The Stanislaus River flows from the high volcanic and granitic summits of the Sierra Nevada in deep canyons. In this respect it has the same general characteristics as the other Sierra Nevada rivers, but there is less of the bare recently glaciated granite as one goes northward from the Tuolumne.

Of the three forks of the river noted on the map as the North Fork, the Middle Fork and the South Fork, the largest and most important is the Middle Fork, feeders of which descend from the summit of the mountains. At some points along its course the canyon in which this branch of the river flows, widens out to the semblance of valleys as at Eureka Valley and Donnell's Flat and at a few other points.

The North Fork lies in a deep and narrow canyon receiving but few tributaries after leaving the summit region of the mountain range. At only one point in this canyon, noted as Ramsey on the map, is there a sufficient widening to justify the assumption of storage possibilities. In the summit region, however, of this branch, as well as on the Middle Fork, are a number of glacial depressions or valleys such as Bear Valley, Silver Valley, Utica Reservoir, Union Reservoir, Kuhn's Meadow and the lower Highland reservoir site on the North Fork; Sand Flat, Kennedy Meadows, Relief Reservoir and Kennedy Lake on the Middle Fork which are or can be made available for some storage of water.

The South Fork of the Stanislaus does not extend to the crest of the Sierra Nevada. Its watershed is long and narrow. Its two principal branches are Herring Creek and Strawberry Creek. On Strawberry Creek are three small reservoirs. There are several reservoirs on the South Fork, some of which have been in use since 1857. These are known as the Lower and Upper Strawberry and the Big Dam reservoirs. These formed a part of the Tuolumne County Water Company's system which has in recent years been acquired by the Sierra & San Francisco Power Company.

Foot Hill Reservoirs Undesirable for City Supply

Should surveys show it possible to divert portions of the Stanislaus water left after satisfying the irrigation priorities into some reservoir that might conceivably be found in the foot hill region, such a reservoir would not be suitable for domestic water supply to San Francisco because of shallow flowage. Algae and other organic growths would flourish under the warm temperature and abundant sunshine, nor would such low altitude permit economic transportation to the city.

Diversions from Stanislaus Into Tuolumne Watershed

About midway the course of the river between the junction of the Herring Creek and Strawberry Creek, and the junction of the South Fork with the Middle Fork, there are several places where the South Fork canyon widens out as at Hales Mill; at Playfair; Lyons Ranch and Lyons Flat. Some of these small storage possibilities have been utilized. At Lyons Flat there is a small reservoir which is part of the old Tuolumne County Water Company's system. This receives the water from the upper South Fork reservoirs, and from it the water is carried by ditch and flume across the summit that separates the South Fork from the watershed of the Tuolumne.

It thus happens that practically all of the water in the old Tuolumne County Water Company's system of ditches taken from the Stanislaus is used in the basin of the Tuolumne River.

The reservoirs already mentioned on the North Fork, the Union, the Utica and Silver Valley are parts of the ditch system belonging to the Utica Mining Company. The water which is liberated from these reservoirs flows in the North Fork to a point about 3 miles southeasterly from the Calaveras Grove of Big Trees and is there diverted into a ditch which carries it out of the canyon into the vicinity of Angels.

The South Fork Storage Reservoirs

The Big Dam reservoir occupies a glacial granitic valley. The dam site is bare glaciated granite. The dam was constructed of large tamarack logs, 2 to 4 feet at the butts, up to a height of about 35 feet. On top of the log cribwork, there was originally an upper section of the dam built of hewn timbers bringing the crest of the structure to a height of about 52 feet above the lowest part of its base. This upper work, however, had been allowed to go to pieces and the dam, when examined by the writer some years ago, was effective only to a height of about 35 feet. The dam has a skin of hewn timbers covered with gravel and earth. The crest length of the original structure was about 460 feet.

The Upper Strawberry dam is built of cedar logs, has a crest length of 584 feet and a maximum height of about 40 feet. This dam is located about 7 miles below Big Dam on a granite reef which crosses the river at the lower end of a flat of about 50 acres. The crest of this reef is irregular and broken and the dam is fitted to it. The main dam is supplemented by a short low earth dam closing a depression where the granite reef approaches the mountain at the northwest and also by an earth filled cribdam closing a narrow gap some 140 feet to the eastward of the main structure. The crest of the dam is at the full height to which storage is practicable at reasonable cost.

The Lower Strawberry dam is about one-half mile above the mouth of Herring Creek. It backs water up to within about one-quarter mile of Upper Strawberry dam. The dam closes a gorge at the lower end of a flat having an area of about 80 acres. The dam has a height of about 40 feet and a crest length of 300 feet. The effective height of the dam was increased by a light upper wall-like structure of hewn timbers which had, however, been allowed to go out of service. The main portion of the dam is built out of logs, with a timber skin.

The storage capacities of these three reservoir sites are indicated in the following table, the estimates being based upon surveys by the writer:

TABLE No. 1—SOUTH FORK RESERVOIR SITES.

Height of dam, feet.	Big Dam.		Upper Strawberry.		Lower Strawberry.	
	Area, acres.	Capacity. acre feet.	Area. acres.	Capacity. acre feet.	Area, acres.	Capacity, acre feet.
10	...	.....	...	.....	...	.....
20	...	.....	...	.....	...	.....
30	124	1,630	...	.....	53	310
40	138	2,940	(75)	(1,200)	65	910
50	148	4,380	...	.....	87	1,660
60	159	5,900	...	.....	105	2,630
70	...	.....	...	.....	115	3,740

The total storage at the greatest hight given in the table is thus seen to be only $5{,}900 \times 1{,}200 + 3{,}740 = 10{,}840$ acre feet equivalent to about 2.5 billion gallons, which is trivial compared with either of the four sites proposed for development by the city on the Tuolumne.

Other Activities and Priorities

The Tuolumne Water Company also had a dam about 11 miles below the junction of Herring and Strawberry Creeks across the South Fork. This was known as the Lyons Ranch dam but served for a few years only. Its left bank abutment rested against an unstable formation which was cut out by the river and no attempt was made to reconstruct the dam after its failure.

This dam was located several miles above the head of the company's ditch.

The capacity of the water company's main ditch, as estimated some years ago, may be noted at about 50 second feet, which is the amount of water that is fairly dependable from the South Fork in its present state of regulation.

This water is conveyed, as already stated, by ditch across the summit which separates the Tuolumne drainage basin from the South Fork of the Stanislaus and is conveyed in a number of branches to various points of use.

The first of these branches is the Eureka ditch which carries water into the vicinity of Sommersville and Soulsbyville. The Columbia branch reaches the vicinity of Columbia and the Bald Mountain branch follows the ridge between Sullivan and Wood's creeks. The water for Phoenix reservoir from which Sonora receives its supply is diverted from the main ditch at a point on the ridge between the Tuolumne drainage and the South Fork known as Whitman Pass. Before reaching Phoenix reservoir this water with a drop of about 1,000 feet is used for the generation of power for which there is a good market.

There is an extensive system of distributing ditches and service reservoirs connected with the several branches above mentioned.

The water which is taken from the Stanislaus by these ditches is in large part carried out from the Stanislaus into the Tuolumne watershed as already explained.

Although these properties have not been offered to San Francisco, reference is made to them to show that the matter of developing a supply for the towns of the lower mountain region received early attention and that there are established rights on the stream which must be considered if any water is to be taken from the Stanislaus for the bay region.

On the North Fork the Utica Mining Company has several reservoirs in use. These are the Utica, the Union and the Silver Valley. They are located high up in the mountains and command only a small watershed.

From Beaver Creek, a south side tributary of the North Fork, a diversion is made by tunnel to increase the natural flow of the North Fork above the head of the Utica canal.

The Utica ditch and flume has a capacity reported at 65 second feet. Its water is used at a power house on Angels Creek near Murphy and then for mining and other purposes, notably the town supply of Murphy and Angels. The waste water from the towns and mines flows back into Stanislaus River below the point where water would be diverted for San Francisco if this stream were called upon to supplement a supply from the Tuolumne River or some other source.

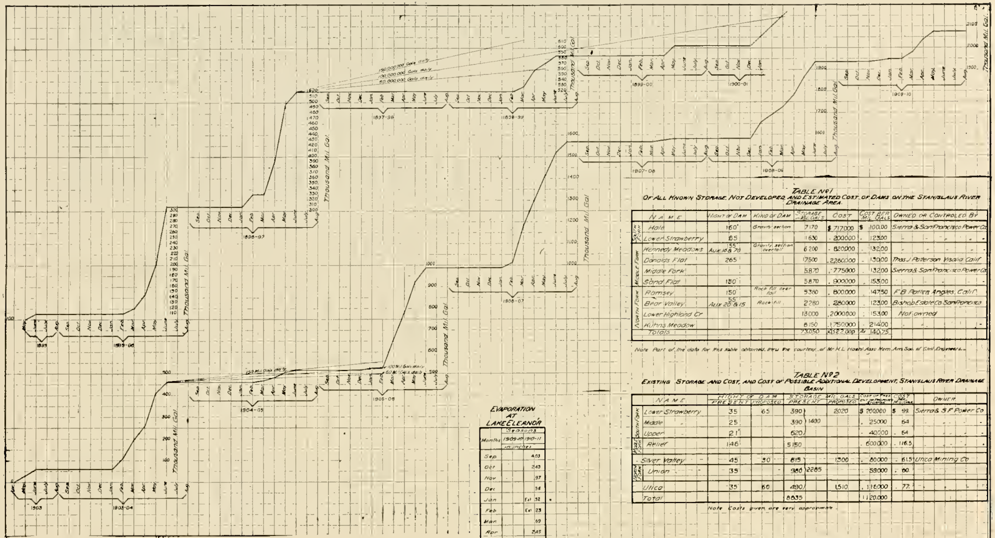
Middle Fork Storage and Activities

On the Middle Fork of the Stanislaus at Relief the Sierra and San Francisco Power Company has a reservoir of a capacity of about 12,700 acre feet. The canal and flume of this company is reported to have a capacity of 375 second feet. The water diverted by this canal from the Middle Fork is used for the generation of power below the mouth of the North Fork and above the point hereinafter described as the point where a diversion might be made for San Francisco. The operations of the Sierra and San Francisco Power Company would tend in some measure to equalize the stream flow, and to this extent the company's operations would prove beneficial to a municipal project. There are upon this river and its tributaries, as upon all of the rivers which drain the slopes of the Sierra Nevada mountains, small diversions of water. These, though appearing in the records as being in the aggregate of considerable moment, need not receive any special notice at this time. Enough has been said to show that the territory drained by the river has been exploited for storage and diversion to a material extent. The diversions which call for the most attention are those which are now being made for the irrigation of broad tracts of land in the San Joaquin Valley, as already mentioned.

Irrigation Requirements

But small part of the water which flows in the river at or near the mouth of Coyote Creek, the probable point of diversion, could be available for San Francisco. There is a large area in the San Joaquin Valley which is dependent upon the Stanislaus River for water. The original plans for the irrigation of the Modesto Irrigation District called for water from the Stanislaus River, and a Stanislaus project was made the basis of the cost estimate which preceded the bond issue. But an opportunity was presented to Modesto District to join with the Turlock Irrigation District in the construction of the La Grange dam, and by the exclusion of a large area which was cut from the northeastern corner of the district as first laid out, the original plans were modified. If the first plan had been carried out rather more than the natural share of the valley land at its south would have fallen to Stanislaus River.

At the present time canals are being constructed by the San Joaquin Irrigation District for the irrigation of 71,000 acres of land lying in San Joaquin Valley north of Stanislaus River and by the Oakdale Irrigation District for the irrigation on the same side of the river of an additional 24,000 acres and of 48,000 acres on the south side of the Stanislaus, a total of 143,000 acres.



EVAPORATION AT LAKE ELEANOR

Months	Seasons 1909-10 in inches	Seasons 1910-11 in inches
Sep		4.03
Oct		2.43
Nov		.97
Dec		.36
Jan		Est .32
Feb		Est .23
Mar		.69
Apr		2.45
May		4.33
June	Record begins	3.96
July	5.84	5.50
Aug	6.21	6.25
Total		31.72

TABLE Nº 1
OF ALL KNOWN STORAGE NOT DEVELOPED AND ESTIMATED COST OF DAMS ON THE STANISLAUS RIVER DRAINAGE AREA.

	NAME	HIGHT OF DAM	KIND OF DAM	STORAGE IN MIL GALS	COST	COST PER MIL GALS	OWNED OR CONTROLED BY
SOUTH FORK	Hale	160'	Gravity section	7170	$ 717000	$ 100.00	Sierra & San Francisco Power Co
	Lower Strawberry	165		1630	. 200000	. 123.00	- - - - -
MIDDLE FORK	Kennedy Meadows	155' Aux 16 & 70	Gravity section overfall	6200	. 820000	. 132.00	- - - - -
	Donalds Flat	265		17500	. 2280000	. 130.00	Thos J Patterson Visalia Calif
	Middle Fork			5870	. 775000	. 132.00	Sierra & San Francisco Power Co
	Sand Flat	150'		5870	. 900000	. 153.00	- - - - -
NORTH FORK	Ramsey	150'	Rock fill over fall	5380	. 800000	. 147.50	F B Pottea Angles, Calif
	Bear Valley	55' Aux 20 & 15	Rock fill	2280	. 280000	. 123.00	Bishop Estate Co San Francisco
	Lower Highland Cr			13000	. 2000000	. 153.00	Not owned
	Kuhns Meadow			8150	. 1750000	. 214.00	- - - - -
	Totals			73050	10522.000	Av 140.75	

Note Part of the data for this table obtained thru the courtesy of Mr H. L. Haehl Asso Mem Am Soc of Civil Engineers.

TABLE Nº 2
EXISTING STORAGE AND COST, AND COST OF POSSIBLE ADDITIONAL DEVELOPMENT, STANISLAUS RIVER DRAINAGE BASIN

	NAME	HIGHT OF DAM PRESENT	HIGHT OF DAM PROPOSED	STORAGE MIL GALS PRESENT		STORAGE MIL GALS PROPOSED	COST OF PRESENT OR PROPOSED STORAGE	COST PER MIL GALS	OWNER
SOUTH FORK	Lower Strawberry	35	65	390	1400	2020	$ 200000	$ 99	Sierra & S F Power Co
	Middle	25		390			. 25000	64	- - - -
	Upper	21'		620			. 40000	. 64	- - - -
MIDDLE FORK	Relief	146		5150			. 600000	. 116.5	- - - -
	Silver Valley	45	30	815	2285	1300	. 80000	. 61.5	Utica Mining Co
NORTH FORK	Union	35		980			. 59000	. 60	- - - -
	Utica	35	60	490		1510	. 116000	. 77	- - - -
	Total			8635			1120.000		

Note Costs given are very approximate.

BOARD OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA.

MASS DIAGRAM OF THE WATER AVAILABLE TO SAN FRANCISCO
FROM THE DRAINAGE AREA OF THE
STANISLAUS RIVER TRIBUTARY TO ROBINSON'S FERRY
802 SQ. MILES.

MAKING DUE ALLOWANCE FOR ALL VESTED AND PRIOR WATER RIGHTS.
PREPARED UNDER THE DIRECTION OF MARSDEN MANSON, CITY ENGINEER,
BY M. J. BARTELL.
JAN 1912.

Only the surplus water of the river after the needs of these districts have been met should be considered available for a San Francisco Supply.

The joint canal for the South San Joaquin and the Oakdale irrigation districts will be the enlargement and extension of an older ditch. The two districts have joined interests in the construction of headworks on the Stanislaus River and in the construction of a main canal.

A small ditch constructed about 1856, which later became known as the Schell Ditch, had its head at Six Mile Bar about 6 miles, by the river, above Knights Ferry. This ditch, of small capacity, skirted the lava capped table mountain on the north side of the river. At one place it was a flume hung by brackets from a vertical cliff, and near Knights Ferry it penetrated, by a short tunnel, the ridge between the Littlejohn Valley and the waters of the Stanislaus. Its waters have long been used near Knights Ferry and in Littlejohn Valley for mining, irrigating and other purposes.

About 1895 this property was acquired by the Stanislaus and San Joaquin Water Company, the ditch was enlarged somewhat and extended so that some of its waters was carried beyond the foothill region, out upon the fertile plains of the San Joaquin Valley. But the types of structures were poor and the canal capacity entirely inadequate to accomplish a satisfactory irrigation of the lands dependent upon this ditch for water. The ditch system in the canal, in the course of time, became the property of Mr. Tulloch and associates. Mr. Tulloch, for many years, maintained a low dam just above Knights Ferry which had furnished power to a mill, and in more recent years he has used a part of the water from the Stanislaus-San Joaquin Canal for the generation of power.

The two irrigation districts have now acquired, by purchase, the Tulloch rights. The original Schell ditch had a capacity of about 20 second feet. It was enlarged about 1897 to a capacity of 40 second feet, and the hanging flume near Two Mile Bar was superseded by a tunnel placed a short distance back from the face of the cliff.

The ditch is now being constructed to a capacity of about 2,000 second feet. It will be used jointly, as explained, by the two irrigation districts. The diverting dam in the Stanislaus River is a double arch structure located some distance below the original head of the ditch.

Several tables relating to river discharge and water utilization contained in the report filed are omitted from this abstract. In reference thereto the following paragraphs are inserted:

Estimates of the river's flow were made by the State Engineer of California for the years 1878 to 1884 and by the U. S. Geological Survey from 1895 to date, except 1901, 1902 and part of 1903. The results of these estimates are noted in the report in Table II. The mean annual discharge of the Stanislaus River is about 1,400,000 acre feet. The least annual discharge of which there is record was 350,000 acre feet (1897-98).

The Quantity of Stanislaus Water Possibly Available for San Francisco

The comparison of the ultimate irrigation requirement with the available supply is made by diagram and the result is noted in Tables III and IV of the report, from which it appears that a reservoir capacity to equalize flow in the amount of 240,000 acre feet would be desirable. About two-thirds of this amount or about 150,000 acre feet would come near enough to fulfilling reasonable requirements. It is found furthermore that in practically every year there would be a surplus, in excess of the requirement to replenish storage that would flow to waste.

From these tables and diagrams it appears that this river might afford some water for San Francisco, and a further study was made of the effect of the withdrawal of an amount of 200,000,000 gallons per day in addition to the probable ultimate irrigation requirement. It was found that it would in such case be desirable to have in service reservoirs with an aggregate effective capacity of about 500,000 acre feet (160 billion gallons); but that there would rarely be any shortage if the storage could be brought up to about 300,000 acre feet (about 100 billion gallons).

From a study of the map, it appears hopeless to secure this amount of reservoir space unless by shallow flowage in the foot hills, but the foot hill possibilities have not been fully investigated.

It may be noted that the project of the South San Joaquin irrigation district includes a reservoir in the outlying foot hills with a capacity of 75,000 acre feet (about 25 billion gallons).

The undesirability of foot hill reservoirs for the city supply has already been commented upon.

Point of Diversion and Aqueduct Route

As a tentative project for estimate purposes it may be assumed that the diversion of water from Stanislaus River would be made near Robinson's Ferry above Coyote Creek. Altho there are dangers of pollution involved and other objections compared with the point of diversion selected for the Hetch Hetchy water, a diversion here near Robinson's Ferry, gives the Stanislaus project the best possible showing as to length of aqueduct and cost of works. There would at this point be a low diverting dam at an elevation of about 850 feet. From this point by tunnel and covered conduit the water would be carried to some point on the river to the southward of

Knights Ferry, where to secure better ground for the conduit and moderate pressure there would be a drop of several hundred feet. The water would then be carried in a 60-inch steel pipe on the bench land south of the river to a point southeast of Oakdale, where it would be practically upon the line suggested in 1901 for the pipe line from the Tuolumne River.

For a description of this line reference may be had to the writer's report on the Tuolumne River project dated July 25th, 1902 (see Municipal Reports, 1902-1903, pages 402-450), and also to the later report by Mr. Manson and the report by Mr. A. M. Hunt and R. Van Norden on the power and pumping stations connected with the Tuolumne River project.

A Stanislaus River project as described would afford practically no power. To raise the water over the Altamont summit or into an Altamont summit tunnel, pumping would be required and the capitalized cost thereof is to be taken into account. If constructed, however, as an auxiliary of a Tuolumne project, the necessary power could be obtained from the Tuolumne, but its cost should still be reckoned in.

On the assumption that this project were carried out with a capacity of 60,000,000 gallons of water per day, as an independent project and with delivery at the south line of San Francisco at an elevation of about 200 feet, its cost would be about as follows:

Cost of 60 Million Gallons Daily from Stanislaus, Pumped Near Altamont

Cost of constructing reservoirs possibly.......	$4,000,000
Diverting dam, on Stanislaus River below Coyote Creek, concrete..............	25,000
Tunnel and conduit about 30 miles; about 7½ miles tunnel at $30 per ft. and 22½ miles conduit at $6.00 per ft....	1,900,800
Steel pipe 60 inches diameter, 270,000 lin. ft., total weight about 105,000,000 lbs., at 6c laid	6,480,000
Crossing of San Joaquin River and of Stanislaus River, including 34,700 ft. of trestle over overflow area; San Joaquin River crossing—3-36 inch submerged cast iron pipes	500,000
	$12,905,800

The following items are taken directly from the estimates of cost by A. M. Hunt and R. van Norden on the "Mechanical equipment of the Tuolumne Project," dated October, 1911, except that 15 per cent is added for engineering and incidentals instead of 10 per cent:

Receiving reservoir at Altamont pumping station, including outlets, valves and conduit to pump suctions..................	139,000
Pumping station complete, including all equipment, buildings, pipe connections and auxiliaries	525,000
Rivetted pipe, 34,000 ft. of double 48-inch force main from pumping station, weight 13,408,500 lbs., including manholes, air-valves and blowoffs.................	804,510
Cut and cover conduit, from top of force main to summit tunnel, 18,500 ft. with capacity of 200,000,000 gals. per day.........	287,500
Tunnels—3 lined tunnels 39,240 ft. in aggregate length, capacity 200,000,000 gals. per day	1,373,400
Rivetted pipe—steel mains connecting tunnels and extending from Altamont to the City line of San Francisco 293,500 ft. double 50-inch; weight 117,850,836 lbs., including manholes, air-valves, blowoff gates, etc.	7,071,050
Bay Crossing—submerged crossing of Mowry Slough and of the Bay at Dumbarton Point—three 36-inch galvanized steel pipes, total length 6,700 ft., with gates and connections	622,850
Bridges, trestles, culverts and special supports on line from Altamont to San Francisco.	435,000
	$24,164,110
Engineering and contingencies—15%.......	3,624,610
Lands and water rights and rights-of-way....	2,500,000
Capitalized cost of operating pumps at Altamont (operating expenses include depreciation) at 5%.....................	9,278,000
Total	$39,566,720

Note: By reducing the capacity of the cut and cover conduit at Altamont and the tunnel capacities to 60,000,000 gallons per day, the foregoing estimate might be reduced about $577,400.

General Remarks

The project of a water supply from the Stanislaus River as here sketched in outline is not a satisfactory one. It does not seem reasonable to hope for an expansion of such a project to greater capacity than the initial assumed 60,000,000 gallons per day, and even this amount it may be difficult, if not impossible, to secure continuously.

There is no storage near San Francisco included in the estimate of cost. The project as outlined would therefore be one of low rank in the matter of reliability of service.

The most that can be reasonably expected from the Stanislaus River is consideration as a source from which a limited amount of water might be added to the water of a Tuolumne River project in the very distant future.

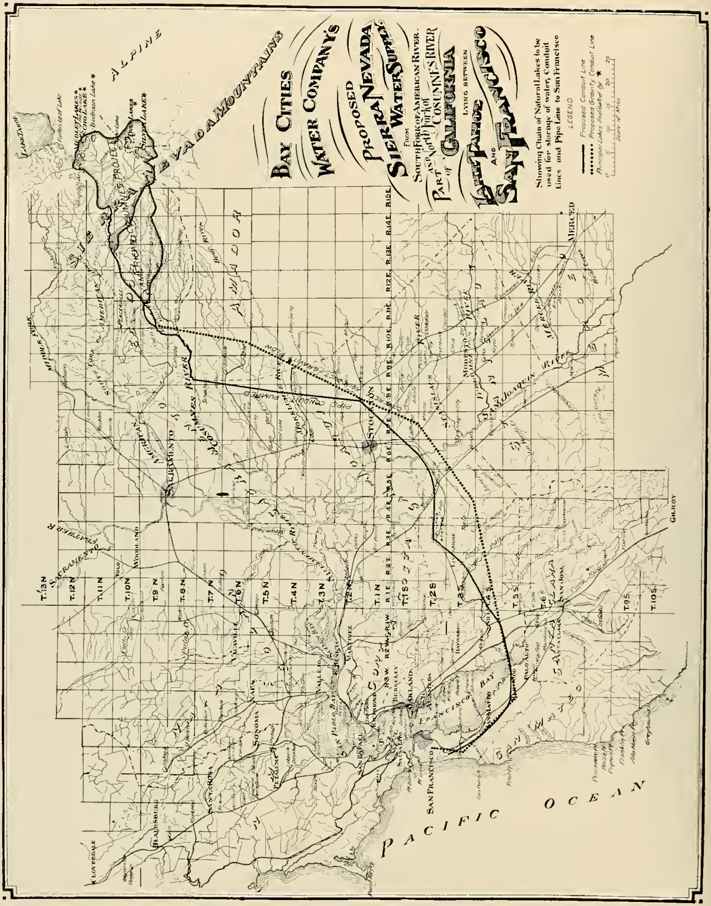
Quality of Stanislaus Water Not Always Satisfactory

The quality of the water as low down on the stream as Robinson's Ferry is an element of uncertainty in this discussion. It would not at all seasons be satisfactory in appearance, due to turbidity, for delivery to consumers without, at least, sedimentation. Neither would it be entirely above suspicion as to sanitary qualities, without filtration, unless it could be passed through some reservoir of large capacity before delivery to the City. No such reservoir has been indicated as a project feature and probably none entirely satisfactory could be secured unless this project is made auxiliary to the established system of water supply.

C. E. GRUNSKY,
Consulting Engineer.

Note—Four of the six sheets of drawings which accompanied this report are not reproduced here. Copies of all were included with the copies of this report placed on file with the Advisory Board of Army Engineers.

Sheet No. 1 Showing catchment and areas of equal rainfall is reproduced.
No. 2 The portion of the catchment in private ownership.
No. 3 Mass diagram of the quantity of water available is reproduced.
No. 4 Provisional route of aqueduct.
No. 5 Profile of conduit and pipe lines.
No. 6 Irrigation districts dependent upon Stanislaus River.
No. 7 Diagram of river discharge and probable utilization for irrigation and city supply.


Bay Cities Water Company's
Proposed Sierra Nevada Water Supply
From South Fork of American River and North Fork of Cosumnes River
Part of California
lying between
Lake Tahoe and San Francisco
Showing Chain of Natural Lakes to be used for storage of water, Conduit Lines and Pipe Line to San Francisco
LEGEND
Proposed Conduit Line
Proposed Gravity Conduit Line
Principal Lakes Indicated by ★
Scale of Miles
0 5 10 15 20 25
Alpine
Sierra Nevada Mountains
Amador
Lake Tahoe
Pacific Ocean
Sacramento
Stockton
San Francisco
Oakland
Berkeley
San Jose
Merced
Gilroy
Santa Rosa
Healdsburg
Cloverdale
Petaluma
Sonoma
Napa
Vallejo
Martinez
Hayward
Palo Alto
Woodland
Vacaville
American River
Cosumnes River
San Joaquin River
Feather R
Sacramento R
San Francisco Bay
San Pablo Bay
Pumped Pipe Conduit
Gravity Conduit
T.13N T.12N T.11N T.10N T.9N T.8N T.7N T.6N T.5N T.4N T.3N T.2N T.1N T.1S T.2S T.3S T.4S T.5S T.6S T.9S T.10S
R1W R1E R2E R3E R4E R5E R6E R7E R8E R9E R10E R11E R12E R13E R14E R15E

Appendix No. 11

THE AMERICAN-COSUMNES PROJECT

Abstract of Report by J. H. Dockweiler, C. E.

(Outline of report filed in triplicate with the Advisory Board of Army Engineers on August 1, 1912.)

The report on the American-Cosumnes project as a source of water supply for the City of San Francisco and adjoining communities of the San Francisco Bay region, by J. H. Dockweiler, Consulting Engineer, dated July 24, 1912, is the result of an investigation of the water resources of the drainage areas on the headwaters comprising the American-Cosumnes project; of the water resources of the catchment of the entire American and Cosumnes rivers; of the total amount of irrigable land within this and the adjacent Sacramento Valley region which naturally looks to these rivers for its future development by irrigation; the water needs of this irrigable land and other general economic features dependent upon the surface water supply of this region.

It is shown that there are about 658,500 acres of irrigable land, requiring about 830,000 acre feet annually, which will be dependent upon the waters of the American and Cosumnes rivers for irrigation.

It is shown that there are about 80,500 acres near where these two rivers debouch into the Sacramento River, which are sub-irrigated and will therefore require no surface irrigation.

The ground water here stands at 10 feet or less below surface, so that if irrigation should be required, it can be done by pumping from wells located within the territory to be irrigated.

The report assumes that after these waters are used for power they will be available for irrigation. (See page 100 of the typewritten report filed.)

It is shown that after fully providing from the waters of the American-Cosumnes rivers drainage areas the 830,000 acre feet annually required for irrigation, there remains an excess of about 220 million gallons daily.

Therefore, assuming that all prior water rights within or having a claim upon the waters from the drainage areas comprising the American-Cosumnes project other than the irrigation future demands just mentioned are acquired by purchase, there would be available for diversion to San Francisco about 220 million gallons daily.

The report filed then takes up for discussion the various engineering features involved in the development and delivery to San Francisco of the waters from this source in considerable detail, and cost estimates are made with summaries, giving the probable cost of development and delivery to San Francisco County line of:

1st: 60 million gallons daily, } by projects requiring pumping
2d: 220 million gallons daily, }
2A: 220 million gallons daily, by an all-gravity conduit.

Power Possibilites on Line of American-Cosumnes Aqueduct

There is a possible power development as follows:

In years of normal runoff 35,200 K. W. (47,168 H. P.) and in years of critical runoff about 18,000 K. W. (24,120 H. P.).

During years of critical runoff, this power is not sufficient to pump the 220 million gallons over Altamont Pass, as required in the aqueduct considered first in this report.

To pump 60 million gallons daily over Altamont Pass requires 7,200 K. W.; 220 million gallons daily requires 26,200 K. W., or about 35,000 horsepower.

In a supplemental report very recently prepared at Mr. Freeman's request, and following his types of structure and his unit costs so far as practicable, it is shown that the waters can be delivered from the American-Cosumnes drainage area to San Francisco on the lines of the Freeman project by gravity—no pumping being necessary, this 24,000 to 35,000 horsepower would then be available for other uses.

A Brief Review of the Report Filed

The report comprises 353 pages, one appendix and supplementary report of 16 pages upon the gravity flow project, and a comprehensive table of contents and index.

The first four pages give very briefly a history of the San Francisco water supply investigations from 1857 to the present time.

On pages 5 to 7, inclusive, are given the causes making this report necessary, namely, permit dated May 11, 1908, by the Hon. Jas. R. Garfield, then Secretary of the Interior; letter dated February 25, 1910, by the Hon. R. A. Ballinger, then Secretary of the Interior, ordering the Mayor and City Council to show cause why the Hetch Hetchy Valley and reservoir permit should not be withdrawn, etc. As a result of the hearing had before the Department of the Interior, pursuant to the letter of February 25, 1910, above mentioned, San Francisco was granted additional time in which to present its case.

Quoting from page 61: "Proceedings before the Secretary of the Interior in re use of the Hetch Hetchy Reservoir Site in the Yosemite National Park by the City of San Francisco."

"Said continuance and postponement is granted for the purpose of enabling said City and County of San Francisco to furnish necessary data and information to enable the Department of the Interior to determine whether or not the Lake Eleanor Basin and Watershed contributary, or which may be made contributary thereto, *together with all other sources of water supply available to said City*, will be adequate for all present and reasonable prospective needs of said City of San Francisco and adjacent bay cities, without the inclusion of the Hetch Hetchy Valley as a part of said sources of supply, and whether it is necessary to include said Hetch Hetchy Valley as a source of municipal supply for said City and County of San Francisco and Bay Cities."

On page 7 is given the basis upon which this American-Cosumnes project is worked out, viz: The determination of the availability of the waters from the American and Cosumnes watersheds for the use of San Francisco and the adjoining bay communities is based on the broad principles of conservation, and on the idea that San Francisco and the allied communities in seeking for a source of water supply are bound to recognize the rights and interests of all irrigable lands and other economic industries having a just and reasonable claim upon the waters in question. Not as a matter of law to be determined by the courts, but on the simple basis of the public welfare.

This American-Cosumnes report, therefore, aims to discover first the amount of irrigable land, the annual amount of water needed by this irrigable land and the amount of water needed by any other economic industries which have any just need from the waters of the American-Cosumnes project. The project is then planned to satisfy all these water needs and considers available to San Francisco only such waters as remain after fully satisfying these prior needs.

Population Studies by Mr. Dockweiler

On pages 7a to 71, inclusive, of the report filed, is given the estimated probable future population of San Francisco and the bay communities, the present water consumption from all sources and for all purposes—domestic, irrigation, etc.—and the probable ultimate development of the waters in the San Francisco bay region and tributary drainage areas.

The present population of San Francisco and the other bay communities is (Census 1910) 728,000.

During the year 1911 these communities used an average of about 100 million gallons daily—51 from surface waters and 49 from wells and underground waters. The estimated probable yield from both surface and underground waters from all available sources is 195 million gallons daily—146 from surface waters and 49 from wells.

It is shown on the basis of the estimated increase in population and the estimated per capita consumption of water, that by the year 1929 San Francisco and the bay communities will be using all the water that can be developed and made available in the San Francisco bay region and the naturally tributary drainage areas.

The population of the San Francisco bay communities in 1930 is estimated at 1,376,000; in 1950 it is estimated the population will be 2,235,000, requiring 355 million gallons of water daily.

As a check on the above population estimates there is given an independent estimate of the future population of the San Francisco bay region, based upon the assumption that the population of a seaport city depends chiefly upon the population of the country economically tributary to it. On this basis, the estimated future population of San Francisco and the bay communities in 1930 is 1,500,000; in 1950, 2,200,000 and in the year 2000, 4,200,000.

On pages 23 to 97, inclusive, are given the hydrographic studies showing that during the most severe period of runoff (namely, the period 1895 to 1900, inclusive) the drainage areas embraced in the American-Cosumnes project would have yielded, with the storage considered, an average of 240 million gallons daily. This is fully set forth on draft sheet, page 96.

On page 24 is given a regional map showing the boundaries of the drainage areas of the American-Cosumnes project, its airline distance from San Francisco bay, the conduit line, etc.

On page 52 in given a map of the American and Cosumnes rivers drainage areas, showing that portion embraced in the American-Cosumnes project, with lines of the mean seasonal or normal rainfall. On this map it is shown that the average cr normal rainfall over the drainage areas of the American-Cosumnes project is from 40 to over 60 inches.

On page 98 there is given a map showing the area embraced by the American and Cosumnes project, the proposed reservoir sites, the location and amount of lands held in private or corporate ownership and the boundary lines of the El Dorado National Forest.

On pages 99 to 169, inclusive, is given a study of the amount of irrigable lands on the American and Cosumnes rivers drainage area and the Sacramento Valley adjacent, the water needs of this area and a general discussion, with tables showing the economic industries, their production of wealth, etc.

On page 102 is given a map showing the irrigable lands.

On page 138 is given a map showing the present water development within the American and Cosumnes rivers drainage areas.

In conclusion it is shown (page 167) that during the most severe period of runoff (1895-1900, inclusive) that there must be allowed to pass from the drainage areas of the American and Cosumnes project for the use of irrigationists, an average of 16.4 million gallons daily and that the net amount of water available for diversion to San Francisco and bay communities is (page 97) 240—16.4, or about 223.6 million gallons daily.

On page 169 it is stated that these waters are of good, potable quality.

On pages 170 to 288, inclusive, are given detailed and summarized estimated costs of all the necessary structures, water-rights, rights-of-way, etc., to develop and deliver the waters from this source to the county line of San Francisco. These costs are given in considerable detail. The designs of all the more important structures are considered in detail and are here set forth as a result of an economic study.

Type and Size of Aqueduct Proposed

The conduit system here first considered contemplates a steel pressure pipe across the San Joaquin Valley and pumping station at Altamont (on the west slope of the San Joaquin Valley) which necessitates the pumping of all the waters over the Mount Diablo Coast Range. Substantially as in the Grunsky and Manson projects for utilizing the waters of the Upper Tuolumne.

This conduit was assumed to be developed and increased as the water needs of San Francisco and the bay communities would demand and as an initial development, the conduit is proposed of a capacity of 60 million gallons daily, to be carried in two pipes each of 30 million gallons daily capacity. The successive additions are assumed to be 3 pipes laid one at a time with several years intervening, each of a daily capacity of 55 million gallons or a total daily capacity for the 5 pipes of 220 million gallons.

All the tunnels and canals are assumed to be initially constructed to the required ultimate capacity, i. e. 220 million gallons daily.

The value of the existing water rights holdings, structures, etc., upon the drainage area of the American-Cosumnes project that would have to be purchased is arbitrarily assumed at $5,000,000.

Gravity Flow Project

Supplementary to this report and following Mr. Freeman's development of a gravity flow plan for the Tuolumne water, an all-gravity conduit has been worked out for the American-Cosumnes project and found to be much cheaper than the conduit previously planned and described above. This will be described later.

On page 281 of the typewritten report filed is given a summary of the estimated costs of the structures necessary to develop and deliver thru 5 pipes 220 million gallons daily to San Francisco, namely, $107,404,762.

On page 288 is given a summary of the estimated costs, as above, for 60 million gallons daily, namely, $36,813,130.

On pages 289 to 353, inclusive, are given the maps of the reservoir sites, canal lines, dam plans, profiles, etc., upon which are based the cost estimates just given.

On pages 364-376, inclusive, is given a supplemental report considering the delivery by an all-gravity route, of 220 million gallons daily from the American-Cosumnes project to San Francisco.

The delivery of water by gravity alone, from the Sierras to San Francisco is made possible by the use of large concrete-lined pressure tunnels and steel concrete-lined pressure pipes, substantially as planned by Mr. Freeman.

The estimated cost for the development and delivery of 220 million gallons daily to San Francisco from the American-Cosumnes project by use of the all-gravity aqueduct is $69,210,710 (page 364).

By using the all-gravity aqueduct no power is necessary to deliver the waters to San Francisco, hence the power heretofore assumed to be used for pumping will be available for other purposes.

The Cat Point power station complete, with accessories and double circuit transmission lines to San Francisco are estimated to cost $5,045,430, which amount is not included in the above estimate of the cost of the gravity aqueduct.

Summarized Statement of the Principal Facts Shown by Mr. Dockweiler's Report on the American-Cosumnes Source

The drainage areas of the American-Cosumnes project are about 350 square miles—mean seasonal rainfall from 40 to 60 inches. The nearest point of this drainage area is, in the air line, about 110 miles northeast of San Francisco. The water is now pure, and with reasonable precautions can be kept so.

On the American and Cosumnes rivers drainage areas and the Sacramento Valley adjacent, there are 658,000 acres of irrigable land requiring for irrigation 830,000 acre feet annually.

79,022 million gallons storage can be developed in 17 reservoirs—11 on the American River drainage area and 6 on the Cosumnes River drainage area. With this amount of storage on hand, the average daily yield from the drainage areas of the American and Cosumnes project during the critical period, 1895-1900, was about 240 million gallons daily. Of this 240 million gallons daily about 16 million gallons daily is needed for irrigation uses. Therefore, the net amount of water available for the use of San Francisco and the bay counties is about 224 million gallons daily.

To develop and deliver 60 million gallons daily to San Francisco (including the installation of sufficient power to pump over the Altamont Pass) will cost about $36,813,130; to develop and deliver to San Francisco 220 million gallons daily (by use of an all-gravity conduit) will cost about $69,210,710.

By the year 1930 San Francisco and the bay counties will be using all the waters that can be developed in the San Francisco bay region and the drainage areas naturally tributary. The population at that time is estimated to be about 1,500,000, or just about twice the population of 1910, namely, 728,000. Population in 1950 is estimated at 2,235,000, which population will require about 355 million gallons daily, and therefore, if proper recognition is given to the requirements for the best agricultural development of this fertile portion of the state, the American-Cosumnes source probably would be outgrown less than thirty-five years hence and a new additional source would then have to be sought.

Appendix No. 12

REPORT ON FILTERED WATER SUPPLY FOR SAN FRANCISCO

By ALLEN HAZEN, Consulting Engineer.

December 4, 1911.

Mr. Marsden Manson,
City Engineer,
San Francisco, Calif.

Sir:—

Pursuant to your instructions, I beg to present the following report, first, upon a filtered river supply from the San Joaquin or Sacramento River, and, second, upon the quality of the Tuolumne water and conditions growing out of the joint use of the catchment area for water supply and park purposes.

The maps of the U. S. Geological Survey covering many of the localities have been largely relied upon, although some of the more important elevations have been checked by aneroid barometer, or otherwise, and personal inspection was made during June and July, in a general way, of the whole region, and in more detail of the sites for the most important structures. Information as to the depths of water has been taken from the U. S. Harbor Chart. Information as to the character of the various waters has been obtained from personal observations of color and turbidity, from records of analyses by the U. S. Geological Survey, from Hyde's Report to the City of Sacramento, from the City Chemist's records, and from analyses by Prof. Edmund O'Neill made for this purpose. Many features of the work have been discussed with Mr. John R. Freeman, with several engineers in San Francisco, and with others, and acknowledgment is now made for numerous valuable suggestions.

PART I

FILTERED WATER SUPPLY

At first it was proposed to consider the Sacramento and San Joaquin Rivers separately. Afterward it became apparent that the greater part of the required plant was common to the two, and the whole matter was studied as one problem.

Capacity of Plant

Pursuant to your instructions, the capacity of the plant is fixed at 60 million gallons per day, but arranged to be capable of maintaining an over-draft of 10 per cent during periods when the monthly consumption is above the annual average, so that the capacity is in reality 66 million gallons per day. Filters, pumps, and other parts not capable of uninterrupted service are provided with sufficient reserve capacity to maintain the full rate of output. This is all considered as the first instalment of a much larger plant to meet remote future conditions, and the more permanent parts of the works, especially the tunnels, are made of sufficient size to serve three units of the size of that first constructed, that is to say, with capacity of 200 million gallons per day.

Position of Intake

In a general way the further downstream the intake can be placed the cheaper will be the supply. The controlling condition is the presence of salt water and the distance that it goes upstream. There is no adequate data to show how far salt water extends at different seasons and with minimum flows. Inquiries were made of Col. Biddle and others, but only general answers were received.

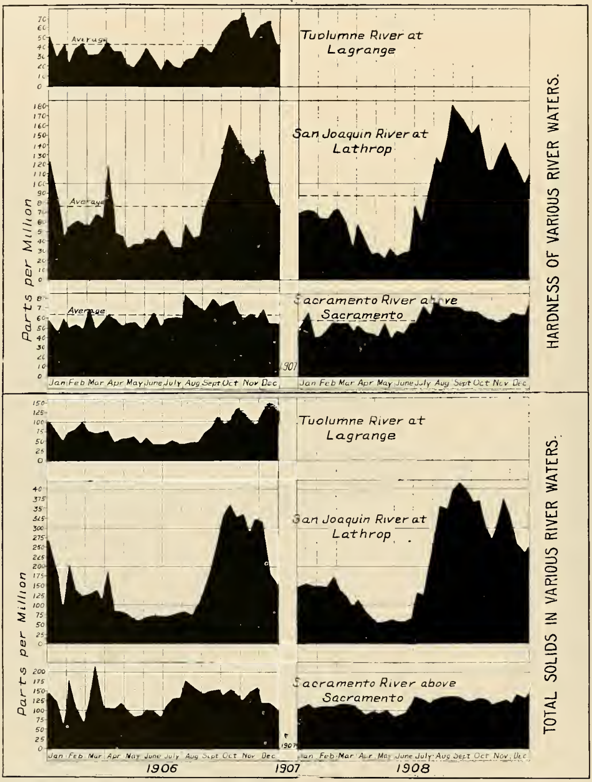
The sugar refinery at Crockett takes water for sugar refining from the river. Sometimes at very high water it is possible to take water at the refinery. Otherwise a tank steamer goes upstream to a point where the water is sufficiently fresh and takes it to the refinery. It is frequently necessary to go thirty miles and at times nearly forty miles, or to a point on the San Joaquin River four miles above Three Mile Slough.

The analyses of water actually used at the refinery indicate that water is frequently used with a greater degree of salinity than would be acceptable for a public water supply.

Antioch, twenty-five miles above the refinery, gets its water supply directly from the river without treatment, and it is said to be generally satisfactory. The water opposite Antioch from another source is stated to have become distinctly brackish during the low water in the fall of 1910.

At the time of my visit the rivers were in flood and the water was no doubt fresh much further down.

The present year has been one of more than average flows, so that any analytical observations now made are inadequate to establish conditions in a dry year. Further, the amount of water used for irrigation is increasing, and this will decrease



Hazen & Whipple, Consulting Engineers,
Aug. 7, 1911. — 103 Park Ave., New York.

the flow of the river, so that after thirty years the distance that salt water goes up may be considerably greater than it has been up to the present time.

Col. Biddle and others expressed the opinion that Rio Vista on the Sacramento would be a safe place of intake, and probably about as low on the Sacramento as would be safe.

The San Joaquin River has a much larger channel in the neighborhood of Antioch than the Sacramento, and also a smaller flow, and brackish water presumably goes up it further than up the Sacramento.

About two miles above Rio Vista water from the Yolo Basin enters the Sacramento River. The water is of inferior quality because it comes from the drainage of the eastern slope of extensive hills and the water afterwards stands in swamps. The mixture of this water reduces the quality of the Sacramento River water to some extent, and it may be considered an open question whether it would not be worth while to extend the intake above the Yolo Basin, or, on the other hand, to shorten it by a few miles by placing it below Rio Vista.

These matters are of secondary importance, and no attempt will be made to investigate them further at this time.

An intake in the San Joaquin River opposite Mandeville Island would be practically the equivalent, from the standpoint of engineering difficulties and cost, of an intake in the Sacramento at Rio Vista.

Sacramento River water is clearly of better quality than San Joaquin water. This is well shown by plottings Nos. 49 and 50 made of results deduced from analyses made by the U. S. Geological Survey, contained in Water Supply Paper 237. These results show the Sacramento River to be not only much softer and more free from mineral matter, but the seasonal variation is much less. In the early summer the difference is not so great, but in the late summer and autumn the San Joaquin River water at Lathrop becomes highly mineralized, and for that reason not well adapted to public water supply. The San Joaquin River water further has a yellow color, while the Sacramento River water is substantially free from color. Both the waters are somewhat turbid, and this turbidity seems to persist at all seasons of the year, although in varying amounts. The navigation in the rivers and the ebb and flow of the tide tend to keep fine clay particles permanently in suspension.

Both the Sacramento and San Joaquin waters are subject to sewage pollution by the towns upon their banks. The largest city upon the Sacramento is Sacramento, and the largest upon the San Joaquin, Stockton.

Treatment of River Waters

The waters of both rivers in their raw state are not suitable for public water supply. They can be filtered so as to greatly improve their quality. The Sacramento River water may be filtered so as to produce a good potable water at all seasons of the year, removing the turbidity, color, and the results of sewage pollution. The San Joaquin River could be similarly purified, but would contain an excess of mineral matter during part of the year. A part of this could be removed at greatly increased expense by softening, while other parts could not be so removed.

The best way to treat the water is by means of mechanical filtration. The raw water will first be treated with a coagulent and allowed to stand in a coagulating or settling basin for some hours, during which the operation of coagulation will take place and the heaviest part of the matters resulting from it will settle to the bottom of the basin, from which they will be flushed back into the river at intervals. The water will then pass to sand filters operating at a rather high rate and cleaned mechanically by a reverse current of filtered water. After leaving the filters, if thought necessary or desirable, the water may be finally treated with hypochorite of lime.

Sacramento River water filtered and purified in this way would be somewhat softer, and would have, on the whole, probably a more attractive physical appearance than the water now supplied in San Francisco, which is delivered after storage in open distributing reservoirs.

If the San Joaquin River water were taken the average hardness would be as great or greater than that of the present supply and during a part of the year it would be much greater.

	Hardness as parts per million calcium carbonate.
On the best available information the average hardness of the water now supplied in San Francisco is in the neighborhood of	100
San Joaquin River water, analyses of 1906-08, about	90
(This is sure to increase with irrigation.)	
Sacramento River water, about	55
Tuolumne at La Grange, including more highly mineralized water from foothills	40
Tuolumne River at Hetch Hetchy, stored in a reservoir holding back the softer water of flood flows, not over	20

It is possible to make a roughly approximate financial estimate of the value of hardness in a public water supply. An allowance of ten cents for each part per million in one million gallons has been assumed to be an average figure.* On this basis a difference of 80 parts per million in total hardness is worth $8 per million gallons. For a supply of 60 million

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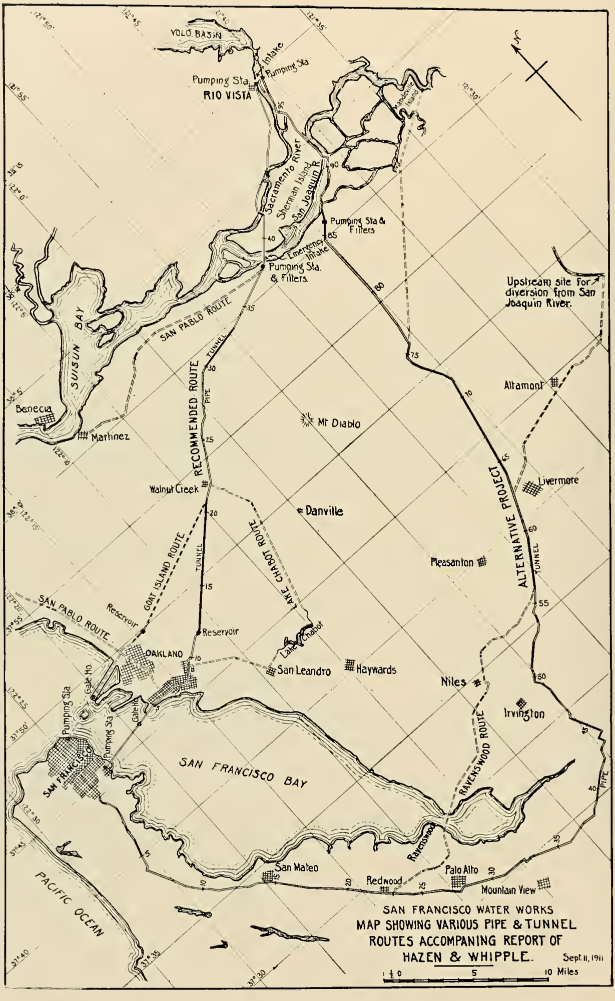
*Whipple, "Value of Pure Water," page 27.



SAN FRANCISCO WATER WORKS
MAP SHOWING VARIOUS PIPE & TUNNEL
ROUTES ACCOMPANING REPORT OF
HAZEN & WHIPPLE.

Sept. 11, 1911

gallons per day this amounts to $480 per day, or $175,000 per annum, and this amount is 5% upon an investment of $3,500,000.

DESCRIPTION OF WORKS

Monte Diablo Route

The route that seems to be on the whole the most advantageous for either the Sacramento River water or the San Joaquin River water passes near Monte Diablo, and I shall call it the Monte Diablo route. The main pumping station and filtration works would be established on solid ground in the immediate neighborhood of Antioch. For the Sacramento River water these works would best be about one mile west of Antioch, while for the San Joaquin they might be three miles east. As the water at Antioch is fresh for the greater part of the year an emergency intake would be provided, and only a single line of pipe would be carried from it to the point of intake. The length of intake to Rio Vista on the Sacramento River is about 14 miles. The line would be 72-inch steel pipe, supplied with water at the intake by a low lift pumping station. Part of the line would be across islands and tule lands with peat soil, and would be liable to settlements. In case of damage or rupture, owing to such settlements or to earthquake shocks, or any other cause, the Antioch emergency intake would be used until repairs could be made to the Rio Vista line, the works below Antioch forming a complete plant capable, without the intake, of furnishing water, although water so supplied would be at times somewhat saline even when taken at low tide.

The main pumping station would pump the filtered water against a head of about 280 ft., through a line composed of about equal parts of steel pipe and tunnel, extending to the base of the hills immediately back of Oakland, where the water would enter a covered distributing reservoir holding two days' supply; from this point steel pipes would pass through the public streets of Oakland and Alameda and through shallow water to a gate house built near the edge of the deep water channel. From this point pipes would be carried under the channel to Potrero Point in San Francisco, a distance of about 3.3 miles, with a maximum depth of water of about 57 ft.

The pipes under the bay would be made of the utmost strength and stability with reference to resisting earthquake shock, and of relatively small size, so that most of the head available from the distributing reservoir will be used up in friction in making the crossing.

At a convenient point on the San Francisco shore a pumping station would be built to pump the water to the various services.

To protect the pipe lines between the distributing reservoir and the bay and under the bay from water hammer in the operation of starting and stopping the pumps, it is proposed to continue the lines a short distance beyond the pumping station to a small reservoir near the top of a hill, at an elevation equal to that of the Oakland Reservoir.

The total length of line from the intake near Rio Vista to Potrero Point, scaled from the maps of the Geological Survey, is 51 miles. It is understood that these maps are only approximately accurate. The route has been inspected in a general way by passing over or near it in automobile or otherwise, and the most important elevations have been roughly checked by aneroid barometer. Many modifications would no doubt be found necessary in developing the project, but it is believed that the topography is sufficiently like that shown to permit the work to be carried out without radical change. Five per cent., however, is added to the scaled length of all pipe lines to cover detours which might be found necessary, and also to cover vertical and other minor curves. No such addition is made for tunnel lines, which it is assumed will be straight.

The route is shown in outline on a map and by a profile accompanying this report. (Nos. 54 and 40.)

Rio Vista Pumping Station and Intake

For the Rio Vista Pumping Station it is proposed to put in centrifugal pumps direct connected to steam turbines and giving a test duty of 80 million gallons on steam, and 60 million as a working average. The much more expensive equipment yielding a higher duty, that might be otherwise installed, would not pay at present prices for fuel oil.

There is a possibility of operating this station by electrical power, but with little prospect of greater economy under present conditions.

Steel Pipe Rio Vista to Antioch

The 72-inch pipe line from the Rio Vista Station to the Antioch Station, for about 8 miles, would be carried on the shore of the Sacramento River a little way back from the marsh, on land sufficiently elevated to be well drained, and to allow economical construction.

In crossing Lone Tree, Sherman and Kimball Islands the soil is largely peat, and settlement is to be anticipated. The peat may also have corrosive action upon the steel. To give the line both flexibility and resistance it is proposed to use a steel shell of the minimum thickness, surrounded with concrete, with sufficient reinforcing to hold it about the pipe in case of moderate movement, and to only partially bury the pipe so that the middle will come to about the elevation of the present surface of the peat, using the excavated material to cover the upper part.

A route following the dykes would have advantages, and it would be possible for a part of the distance.

The river crossings would be made by forming pipe to fit the bottom of the channel, putting it together in fairly long sections and sinking it in channels excavated in advance, making flange connections, where necessary, by divers between adjoining sections, as was done in Connecticut River crossing at Springfield, Mass.

It is not considered necessary to duplicate any part of this line as the supply may be maintained temporarily from the Antioch intake in case of accident.

Filters

The nominal capacity of the plant is 75 million gallons per day, allowing the full capacity of the plant to be maintained with several units out of commission.

Six hours storage of raw water is considered necessary or desirable for Sacramento River water, but in view of the long line of raw water pipe from Rio Vista and the possible difficulty of operating it at all times at the required rates, additional raw water storage will be desirable in operating the plant, and it is proposed to provide 40 million gallons, or two-thirds of an average day's supply.

This would also be especially useful whenever the emergency intake was used as it would permit most of the water to be taken at low tide, when the salinity was least.

Pure water storage need only be large enough to allow reasonable freedom in the operation of the filters and pumps, say three hours' supply, or 10 million gallons.

The filters will be similar in general construction to those at Watertown, Hackensack, Cincinnati, Columbus, etc., with a net area of 27,00 sq. ft., provided with houses, laboratory, regulators, interior equipment, coagulant applying devices, coagulant storage and all appurtenances. The coagulating basins and raw water storage may be open reservoirs, but well baffled, and with arrangements for economical removal of sludge, about 15 ft. deep and with a net area of about 8 acres. The pure water reservoir should be covered to prevent the growth of microscopical organisms in the filtered water.

Antioch Pumping Station

This would immediately adjoin the filters, and all the auxiliary filter machinery would be placed in the same building with it.

Four 20-million triple expansion vertical flywheel pumps are proposed, with a working lift of 280 ft., with boilers and all auxiliaries installed in a steel and concrete station building.

In addition to the main equipment there would be provided an emergency intake extending into the river opposite, and direct connected steam turbine centrifugal pumps sufficient to pump a supply to the basins with a lift of about 20 ft., in case of disability of any part of the intake works. Some excess pumping capacity in the centrifugal pumps will permit them to be operated for only a part of the time at low tide when the water is least saline.

Steel Pipe

Twin lines of 54-inch steel pipe, ranging in thickness from 5/16 to 7/16 inch would be used.

The methods of construction will be similar to those that have been used on other large steel pipe lines, but the depth of cover may be less, and in crossing valleys or other exposed places, pipe may be supported on masonry piers and left exposed for any reasonable distance.

Tunnel

The tunnel is to have an area equal to that of a circle 10 feet in diameter lined with concrete throughout. A horseshoe section about ten feet high and nine feet wide would meet this requirement. Shafts cutting the tunnel up into lengths of about 1.5 miles, ranging from 180 to 380 feet deep, are proposed.

Oakland Reservoir

This is to be a large covered reservoir, to balance hourly fluctuations in the rate of draft in San Francisco, and in general to safeguard any accident to any part of the system back of it. The proposed flow line is at Elevation 195, with water 25 feet deep, holding two days' average supply, or 120 million gallons. The net average area is 12.3 acres, but with embankments it will require 18 or 20 acres, and with land bought for a future enlargement, 50 acres of land will be required.

Pipe Line from Oakland Reservoir to San Francisco Bay

Two lines 48-inch steel pipe are proposed to be laid through city streets. Through the shallow water from Alameda Point to the edge of deep water, about 2 miles, it is proposed to lay four lines of 36-inch cast-iron pipe with a flexible joint every eight lengths. These lines will all be connected with each other on the edge of deep water in a terminal gate house built on piles.

Bay Crossing

From the terminal gate house to the San Francisco shore it is proposed to lay four lines of 30-inch cast iron pipe through water with a maximum depth of 57 feet. These lines to be made with very numerous flexible joints of approved construction, designed to give them the greatest possible strength and reliability, and especially under earthquake conditions. The pipe lines of the present supply, crossing the bay at Ravenswood Point, which went through the earthquake of 1906 without damage, furnish a precedent for this construction.

It is further proposed to have on hand, piled up ready for immediate use, the material for an additional line of pipe, and have stubs provided for several such lines on either end, so that in case of an emergency it could be laid with the least possible delay. Pipe for one such line is enough, for while it was being laid pipes for other lines could be cast and shipped.

Pumping Station in San Francisco

It is not thought wise in any event to attempt to carry a considerable amount of pressure into San Francisco under the bay. A pumping station will be established on the San Francisco side to pump water to the various distributing reservoirs and as required.

The Oakland Reservoir will have a flow line of about 195. It will not be unreasonable to expect iron pipes under the Bay to carry as much of this water pressure as is left after the friction is provided for, but the pipes ought to be protected from water ram incident to starting and stopping the pumps. With this done the pumps will run under whatever back pressure is available from the open reservoir and the fuel consumption will be reduced thereby.

No storage of water before pumping in San Francisco will be required under this plan, as the Oakland Reservoir will provide whatever is needed, and there should be some excess pipe capacity between Oakland and San Francisco to provide for fluctuations in rate of pumping.

The city pumping station is not included in the work covered by this report, but is to be otherwise arranged for.

CROSSING SAN FRANCISCO BAY

As this is clearly the most difficult part of the project, some further discussion of it may appropriately be made. The greatest depth of water on the proposed line from the U. S. Harbor Charts is about 57 feet; the distance across deep water is 3.3 miles, or 17,400 feet. The objection to the crossing is the liability to damage of the pipe lines by earthquake and the difficulty of repairing them.

The alternate procedure is to carry the pipe around the Bay and up the Peninsula to San Francisco. The added distance for doing this for Sacramento River water is between 40 and 50 miles, according to the intake selected. This represents an added cost of at least $300,000 per mile, or $12,000,000 to $15,000,000 for the first instalment alone, and in addition the great cost of pumping all the water more than twice as high.

Rock Tunnel Under the Bay

This is a possibility. This method is now being used to carry the Catskill water under the Hudson River above West Point. No one knows how deep the rock may be. There is water 400 feet deep in the Golden Gate. Presumably it is at least this deep to rock in the main channel, and it may be deeper. This method of crossing is excluded, not as necessarily impossible, but as one on which certain information does not exist, and cannot be reasonably obtained within the limits of this inquiry.

Tunnel Through Soft Material Driven with Compressed Air

There would be no special difficulty in driving such tunnel, as the greatest depth of water, 57 feet, would not call for a very high air pressure. Such tunnel would not be expected to carry much water pressure but might be expected to deliver to the pump well on the San Francisco side, 10 to 20 feet above the tide level. Allowing a slope of 1 per 1000, or 18 feet for the crossing, a 9-foot tunnel would deliver 220 million gallons per day. The objection to such a tunnel is that it might be broken by earthquake, and when so broken it would be difficult or impossible to repair it and the city would be indefinitely without water while other works were being built.

Pipe Crossing

The estimate is based upon four lines of 30-inch pipe buried a short distance below the harbor bottom. The lines to be of heavy cast iron pipe with flexible joints, similar to the present lines at Ravenswood Point, but with all the improvements in the joints that can be made. It would be the intention to give the line sufficient flexibility so that it might be expected to withstand any minor earthquake shock not involving a slip upon the fault supposed to exist under the Bay. It is understood that the violence of the movement accompanying a slip on the said fault would be so great that it is not expected that any structure would exist through it.

There is believed to be a fault under the Bay, but whether it is a live one to the extent that it may be reasonably expected to move within a few hundred years is not known. The number of old fault lines in the neighborhood of San Francisco is very great indeed. Probably most of them are healed so that there is no prospect of movement within a perid which may be reasonably contemplated in laying out works, and the faults under the harbor are as likely to be of this character as otherwise. In this case there is a reasonable prospect of long life for either a tunnel driven underneath, or for pipe lines laid as described. The difference in favor of the pipe line is that in case of a shock or a break it would be possible to replace it in a much shorter time.

The cost of laying this pipe would be relatively low. The 30-inch steel pipes under the Connecticut River at Springfield cost about $50 per lineal foot for pipe and laying each line laid complete, supported on piles driven in the bottom and cut-off and surrounded by concrete placed in bags. These lines have a working pressure of 150 pounds, were laid with special care, and are perfectly watertight. The lines are altogether too rigid to be adapted to San Francisco earthquake cinditions. The flexible joint line would be both safer and cheaper, although perhaps not as watertight. On the basis of the Springfield work, four lines at $50 each would cost $200 per lineal foot, or, adding 50% for increased cost under California conditions, $300 per lineal foot.

Cost of Flexible Joint Pipe

This pipe would weigh, standard designs, 1⅜ inch thick for high pressure, 530 lbs. per lineal foot, and would cost f. o. b. San Francisco about 2.25 per lb., or about $12 per lineal foot, or for the four lines and one spare line, $1,040,000.

Cost of laying is a matter of great uncertainty. Under favorable conditions it might be very cheaply done. Under unfavorable conditions there might be many delays and losses, and great expense for divers, and contract prices on this kind of work generally run high. I estimate for laying $50 per lineal foot for each line, a total of $3,500,000, and I make a further allowance of $660,000 for extraordinary expenses to bring the total to $300 per lineal foot.

ALTERNATE ROUTES

The alternate routes considered are shown in outline upon a map attached to this report, upon which the distances in miles have been marked.

Goat Island Route

The first part of this route would be the same as the Monte Diablo route. After passing the Ygnacio Valley the tunnel would lie to the right and terminate three or four miles farther north. The route would then follow through the streets of Oakland and through shallow water just north of the Key Route pier, to a point opposite the end of that pier, then under the water to Goat Island, through Goat Island in a tunnel above high tide, then under the main harbor channel 1.7 miles, to the land just below Telegraph Hill. It would be a little shorter to go to the ferry house or to Rincon Point, but the site near Telegraph Hill is believed to be more available for a pumping station.

This line would be about two miles shorter. The principal objection to it is the maximum depth of water, which is about 130 feet, and so deep as to make it impossible to use divers upon the line. Pipe laid on this location would have to be put together, and sunk with the idea that it would last as long as it would, and that no repairs could be made, at least in the deeper portion of the channel.

A profile of this line is drawn upon sheet No. 52.

Lake Chabot Route

The line would follow the Monte Diablo line to Walnut Creek, thence following the Ramon Valley for about three miles, then through a tunnel to North Leandro Creek, a short distance above Lake Chabot; from Lake Chabot the pipe would pass through public streets of San Leandro, and thence to and through Alameda, rejoining the main line at Fruitvale. This line is about seven miles longer than the Monte Diablo route. The summit level is a little higher, owing to the level of Lake Chabot and the topography of the valleys at either end of the tunnel.

It would not do to pump filtered water into Lake Chabot. Raw water would be pumped to this point, and filters could be located on the outlet of Lake Chabot, in which case the water naturally obtained from it would be filtered, together with that drawn from the Sacramento River.

This route has the advantage of making the storage of Lake Chabot available at a point relatively near the city, in connection with the main supply. It is possible only in case a water district should be formed, taking over the ownership of Lake Chabot.

San Pablo Route

This route is intended to avoid the long tunnels on the Monte Diablo line. The route would diverge at Antioch and would follow more or less closely the route of the Southern Pacific Railroad to Oakland, keeping to the south, however, at Vine Hill, to avoid the salt marshes. A considerable part of the route would be on public roads. Parts of it would be along the north shore where the hillside is steep to the water's edge, and where bad sidehill location above the railroad would be necessary. The Geological Survey sheets do not cover the whole of this route, and the harbor map was used for filling in. The additional length to Potrero Point would be about 18 miles, or via Goat Island, about 15 miles. The pumping lift would be considerably increased because of the increased length and the greater friction in pipe as compared with tunnel. The increased length is so great that the line is clearly less desirable than the Monte Diablo route. It will cost more to build the pipe around than to cut the tunnel through.

Livermore Pass Route

This route would follow the line described in Mr. Grunsky's report from the Altamont Pumping Station to San Francisco, a distance of 78 miles, except that a tunnel would be driven under Livermore Pass with a summit level of about 500 feet, or 250 feet below the present surface of the ground.

To go from the intake at Rio Vista to San Francisco by this route would be about 100 miles, or twice the length of Mt. Diablo route. The Geological Survey maps do not cover the whole of the route, so some parts of it have been filled in from other maps, which do not show the topography and are otherwise probably less accurate, but with such inspection as was possible and other information as to the character of the country to be passed.

From an intake on the San Joaquin River on Mandeville Island near the junction of the main river and the middle river, it would be about 51 miles to San Francisco by the Mt. Diablo route, and about 93 miles by the Livermore Pass route. The Mt. Diablo route involves 12 miles of tunnel, and the Livermore Pass route about 16 miles. The summit level on the Mt. Diablo route is about 230 feet, and on the Livermore Pass route about 500 feet.

If the intake were moved to the nearest point on the Old River, a few miles below Tracy, the approximate distance by way of Livermore would be 80 miles, while if the intake were placed at the nearest point on the main river near Lathrop the distance would be 90 miles. It is to be expected that intakes at either of these last-named places would be short of water during the latter part of the year, or at best would only get seepage water containing an excess of mineral matter, and otherwise undesirable for public water supply.

The shortest line that could be practically used would fall somewhere between the Lathrop line and the Mandeville Island line, or between 90 and 93 miles. In a general way this route is 40 miles longer than the Mt. Diablo route, and has a summit level twice as high. This route is shown in outline on plan No. 54, and in profile on plan No. 52, accompanying this report.

Ravenswood Point Route

This is a modification of the Livermore Pass Route. Pipes would be carried across the bay at Ravenswood Point near the location now occupied by the Spring Valley pipes, and near the new railway bridge. The distance across the water is one mile, and the maximum depth 60 feet. In addition, there are about five miles of salt marsh to be crossed.

The object of this variation is to save distance, and about seven miles would be saved as compared with the route going entirely around the bay. The longer route would provide for keeping the pipe above tide water and accessible for immediate repairs at all points. The Ravenswood Point route is open to all the objections that apply to the Alameda-Potrero Point crossing. The distance is one-third as great, but the depth of water is practically the same.

The pipes of the Spring Valley Water Company at this place went through the earthquake of 1906 without damage. Probably well laid pipes would go through other earthquakes as long as there was no movement on a fault line which may exist under the bay. Movement on such a fault line would perhaps be as likely to rupture pipes at Ravenswood as between Alameda and Potrero Point. The only difference would be that it would be a shorter job to lay new pipes for one mile than for three miles.

If it is good business to go forty or fifty miles or more around to avoid a submerged crossing three miles long and to keep all of the pipes accessible, it is worth while to go seven miles further to avoid a submerged crossing one mile long.

The Ravenswood Point Crossing is a compromise, having in slightly reduced measure all the objections to the Alameda-Potrero Point crossing, but without benefiting by the great saving in distance which the latter effects.

Summary as to Alternate Routes

Of these alternate routes the only ones deserving further consideration are the Lake Chabot route and the Goat Island route.

The former cannot be considered as an independent proposition, not contemplating ownership of the Oakland works. The Goat Island route offers several important advantages, along with the disadvantage of much deeper water.

Advantages of Having New Supply Come from Another Direction

The present water all comes up through the Peninsula. If the new water were to be brought in by Livermore Pass and around the bay, the new pipes would follow substantially the same routes as the pipes of the present supply for a considerable distance, and this distance would lie along, and within two miles of, the fault that slipped in the last earthquake. This is perhaps more likely to be the point of disturbance in the next earthquake than any other. Another slip on the same fault might disable all the pipes leading to the city.

Bringing the water in through Alameda has the advantage of entering the city from another direction, and has the advantage that there is a chance in case of a bad earthquake that the lines from one direction or the other may remain intact. An earthquake like the last one might wreck the Peninsula sources, but would not necessarily wreck those coming from Alameda. As, for instance, the pipes of the company under the bay at Ravenswood were not wrecked in 1906.

On the other hand, if there should be an earthquake due to movement on some other fault under the bay, or to the eastward toward Antioch, it might disable the new line, but there would seem to be a fair chance that the Peninsula sources would not be disabled by such a shock.

ESTIMATES OF COST.

In estimating the cost of construction and operation, the best guides are like costs of similar works already in operation. In this case the works most available for comparison are mainly in the East, where costs are quite different from those in California.

It has been necessary, however, to take the actual costs of eastern plants as a basis in making estimates, and in applying them to San Francisco conditions I have taken into account that freight rates on the materials which would have to be shipped, entering into construction, would range from $13 to $20 per ton, as against an average of probably not more than $3 per ton to eastern points, and that because of these rates steel pipes and other heavy supplies would cost from one-third to one-half more than with average deliveries at eastern points.

I have also taken into account the greater cost of labor on the Pacific Coast, and the provision of a minimum wage of $3 for eight hours on city works.

These conditions will increase very greatly the cost of constructing the proposed works.

The availability of cheap fuel oil in California tends to keep the cost of operation down, and the increase in cost of operation over eastern conditions will not be as great as the increase in cost of construction.

The following is a *Schedule of Works*, with approximate estimate of cost:

Rio Vista intake, 500 feet long, ⅜ x 72-inch steel pipe, 347 pounds per foot, at $80.00	—	$ 40,000
Rio Vista Pumping Station, 5 steam turbine centrifugal pumps, each with 20 million gallons capacity, against 80 feet maximum lift, installed complete	$50,000	
Water tube boilers, 1,600-horsepower	32,000	
Foundation, piping, building, stack and auxiliaries	123,000	205,000
72-inch steel pipe, ⅜ inch thick, 347 pounds per foot, but with 5/16-inch pipe backed with concrete for parts of the distance where the line is through peat, from Rio Vista to the Antioch Works, 71,000 feet, at $21.40	—	1,520,000
Sacramento River crossing, extra work in placing and protecting steel pipe	—	50,000
San Joaquin River crossing, ditto	—	50,000
Antioch emergency intake, 500 feet ⅜ x 72-inch steel pipe, at $80.00	—	40,000
Antioch emergency pumping station, 30-foot lift, steam turbine equipment, complete	—	100,000
Mechanical filters, 75 million gallons capacity, 27,000 square feet, including house, laboratory and all equipment, coagulant appliances and miscellaneous unclassified expenses, at $33.33	—	900,000
Coagulating basins and raw water storage, open, baffled, and with arrangements for economical removal of sludge, 40 million gallons capacity, at $9,000.00	—	360,000
Pure water reservoir, covered, 10 million gallons capacity, at $13,000.00	—	130,000
Antioch Pumping Station, 4 triple expansion vertical flywheel high-duty pumps, installed complete, 20 million capacity against 280 feet maximum lift	$600,000	
Water tube boilers, 2,500-horsepower	50,000	
Building, foundations, connections, auxiliaries, and all appurtenances	550,000	1,200,000
54-inch steel pipe, thickness ranging from 5/16 to 7/16-inch, according to pressure, average ⅜-inch, 263 pounds per foot, 26,500 feet, two lines, at $15.64	—	829,000
Tunnel 10 feet high, about 9 feet wide, equal in area to a circle 10 feet in diameter, lined with concrete, 17,400 feet, at $65.00	—	1,131,000
Shaft on same, 360 feet deep, at $65.00	—	23,000
54-inch steel pipe, 5/16 inch thick, 221 pounds per lineal foot, 53,200 feet, two lines, at $14.00	—	1,490,000
Tunnel of the same dimensions as above, 8.7 miles, 45,800 feet, at $65.00	—	2,976,000
Shafts on same, five, 1,570 feet, at $65.00	—	102,000
Oakland covered distributing reservoir, flow line elevation 195, 25 feet deep, 120 million gallons capacity, economical site apparently available in a natural depression, at $8,500.00	—	1,020,000
48-inch steel pipe, 5/16 inch thick, 198 pounds per lineal foot, 36,000 feet, two lines, at $12.37	—	890,000
Resurfacing streets through Alameda and Oakland, the pavement most of the way not being of an expensive character, $1.00 per lineal foot for each line	—	72,000
36-inch cast iron pipe, 492 pounds per lineal foot, laid on the bottom, water less than 10 feet deep, with a flexible joint every 8 lengths, and covered with backfill, 11,000 feet, 4 lines, at $15.00	—	660,000
Terminal gate house on edge of deep water, supported on piles, giving cross connections between all pipes	—	100,000
30-inch cast iron pipe, 1⅜ inches thick, 530 pounds per lineal foot, laid under the bay in a dredged channel, of flexible joint pipe of superior design, and covered afterward, 4 lines, 17,400 feet, 18,440 tons, at $45.00 per ton	$830,000	
Pipes for a fifth line, in reserve, to start work immediately in case of damage or accident, 4,610 tons, at $45.00	207,000	
Laying, $50.00 per lineal foot for each line	3,480,000	
Gates, lead for joints, other supplies and allowed for extraordinary expenses and contingencies	683,000	5,200,000

36-inch cast iron pipe to pumping station, 2,200 feet, 4 lines, at $13.00	—	115,000
48 x 5/16-inch steel pipe, carried uphill to about elevation 200, with a small chamber and open end to prevent water ram, 2,000 feet, at $12.40	—	25,000
Sum	—	$19,228,000
Add 15 per cent for engineering and ordinary contingencies, and 5 per cent in addition for extraordinary contingencies, the work being only roughly outlined and many subsidiary structures omitted or overlooked, in all 20 per cent	—	3,845,600
Total	—	$23,073,600

Land and Right of Way.

Site of Rio Vista Pumping Station, 10 acres, at $1,000.00	$10,000	
Right of way on northwest shore of Sacramento River, from Rio Vista to Line Tree Island, 9 miles long, 100 feet wide, 109 acres, $200 per acre	22,000	
On Sherman Island and Kimball Island, 3 miles, 100 feet wide, 36 acres, $1,000 per acre	36,000	
Site for Antioch works, with room to greatly enlarge plant, 160 acres, at $500 per acre	80,000	
Right of way from Antioch for steel pipe, 4.6 miles, 100 feet wide, 56 acres, at $300 per acre	17,000	
Right of way for tunnel, also space for spoil banks, 60 acres, at $50 per acre	3,000	
Right of way for pipes, about 2 miles in public roads, 7.6 miles through most highly cultivated land, 92 acres, at $1,000	92,000	
Right of way for tunnel, 8.6 miles, with allowance for shafts and spoil banks, 200 acres, at $200	40,000	
Site for Oakland Reservoir, 50 acres, land now being used for suburban development, and held for building lot prices, some buildings already upon it, 15 cents per square foot, $6,500 per acre	325,000	
Sum	$625,000	
Add for surveys, searching titles, legal expenses and expenses of condemnation, 50 per cent	312,000	
Total allowance for land and right of way	—	937,000
Total estimated cost of plant, complete	—	$24,010,600

Estimated cost of installing second and third units, each with a nominal capacity of 60 million gallons per day, at current prices, all the items of expense being the same as for the first installment, except for land and tunnels.

These amount to $18,000,000 for each installment.

The cost of works at current prices would therefore be:

For the first installment, including land and tunnels, for 180 million gallons per day, 60 million gallons capacity	—	$24,000,000
For two installments, 120 million gallons capacity	—	42,000,000
For all three installments, 180 million gallons capacity	—	60,000,000

Intermediate capacities could be obtained after the first installment was built at nearly the same proportionate cost. That is to say, half the second installment could be built, bringing the capacity to 90 million gallons, for a sum not greatly in excess of one-half of the cost of the whole second installment.

Cost of Operation

Rio Vista Pumping Station.

45,000 barrels fuel oil per annum, at 85 cents	$38,200	
Lubricants, lights and supplies	8,200	
One chief engineer	3,000	
Two assistant engineers, at $2,000	4,000	
Seven oilers, at $1,200	8,400	
Seven firemen and boiler men, 810 average horsepower developed, at $1,200	8,400	
Two machinists and repair men, at $1,500	3,000	
Labor employed occasionally for care of grounds and miscellaneous work, average of five, $900	4,500	
		77,700

Antioch Pumping Station.

95,000 barrels fuel oil per annum, at 85 cents	$81,000	
Lubricants, lights and supplies	12,500	
One chief engineer	3,600	
Three assistants, at $2,500	7,500	
Eleven oilers, at $1,200	13,200	
Eleven firemen, at $1,200	13,200	
One machinist	1,800	
Two assistant machinists and fitters	3,000	
One painter	1,500	
One electrician	1,500	
Additional labor employed occasionally for care of grounds and miscellaneous work, average of ten, 300 days per annum, at $3.00	9,000	
		147,800

Operating Filters.

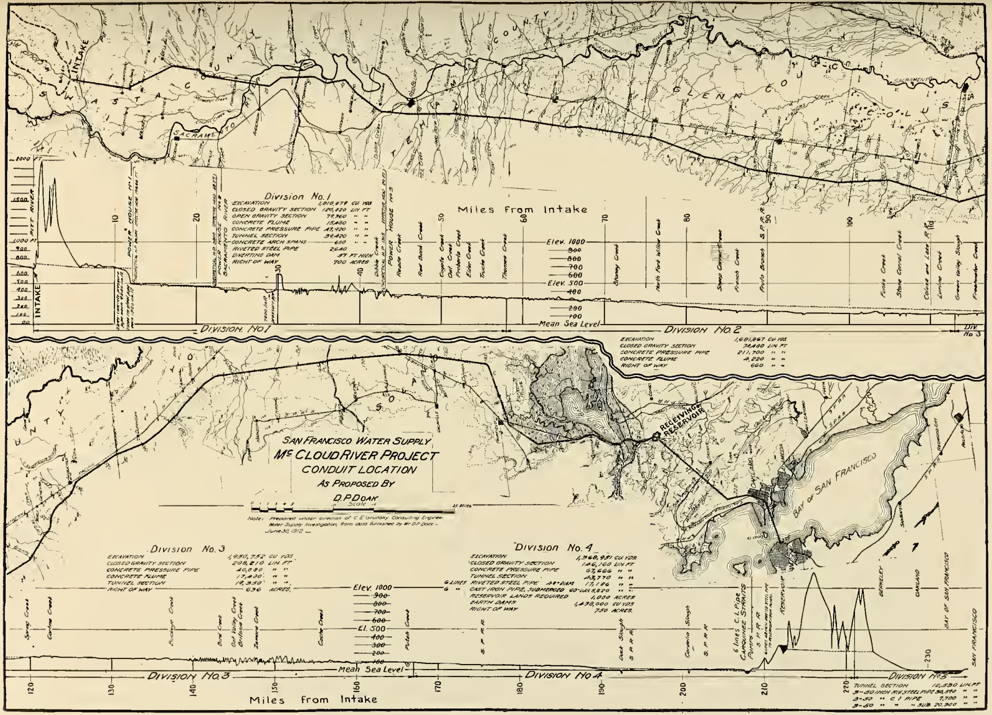
Sulphate of alumina, 1 grain per gallon, 1,600 tons per annum, at $32.00	$51,000	
Chloride of lime, 10 pounds per million gallons, 110 tons, at $40.00	4,400	
Fuel for power, lights, new sand for replacing waste, renewals and repairs of less durable parts	11,000	
One filter superintendent	3,300	
One assistant superintendent and chief chemist	2,100	
Second assistant chemist	1,500	
Laboratory helper	1,200	
Three coagulant feed men	3,600	
Seven filter men	8,400	
Two machinists	3,000	
One electrician	1,500	
Labor employed occasionally to keep grounds in order and to do miscellaneous work, equal to an average of ten men, 300 days per annum, at $3.00	9,000	
		100,000

General.

Five pipe walkers, $1,200	$6,000	
Telephone service to various stations and to the city	1,500	
Automobiles, motor boats and facilities for inspecting all parts of the line and of the river waters, above and below the intakes, allow per annum	7,000	
For occasional labor, repairing damage to pipe line by washing, repairing minor leaks, and making such repairs as cannot be made by the pipe walkers, and for divers occasionally employed on the harbor and river crossings, allow per annum an average of	20,000	
General supervision of whole plant, about 3 per cent of operating expenses	10,000	
		44,500
Total estimated cost of operation for an average output of 60 million gallons per day	—	$370,000
Cost per million gallons	—	$16.90

The greater part of the operating expense is in proportion to the quantity of water treated, and for the present purpose a uniform operating expense of $17.00 per million gallons may be taken.

Note: The remainder of this report relates to quality of the Tuolumne water, and is presented on pages 53-57.



SAN FRANCISCO WATER SUPPLY
Mc CLOUD RIVER PROJECT
CONDUIT LOCATION
AS PROPOSED BY
D. P. DOAK

Scale 0 1 2 3 4 5 10 15 25 Miles

Note: Prepared under direction of C. E. Grunsky Consulting Engineer Water Supply Investigation, from data furnished by Mr. D. P. Doak — June 30, 1912 —

Division No. 1

EXCAVATION	1,810,679	CU. YDS
CLOSED GRAVITY SECTION	120,820	LIN FT
OPEN GRAVITY SECTION	79,360	" "
CONCRETE FLUME	15,480	" "
CONCRETE PRESSURE PIPE	47,420	" "
TUNNEL SECTION	39,420	" "
CONCRETE ARCH SPANS	600	" "
RIVETED STEEL PIPE	2,640	
DIVERTING DAM	57	FT HIGH
RIGHT OF WAY	700	ACRES

Division No. 2

EXCAVATION	1,681,867	CU. YDS.
CLOSED GRAVITY SECTION	74,480	LIN. FT
CONCRETE PRESSURE PIPE	211,700	" "
CONCRETE FLUME	4,220	" "
RIGHT OF WAY	660	" "

Division No. 3

EXCAVATION	1,950,752	CU YDS.
CLOSED GRAVITY SECTION	208,210	LIN FT
CONCRETE PRESSURE PIPE	40,080	" "
CONCRETE FLUME	17,480	" "
TUNNEL SECTION	19,350	" "
RIGHT OF WAY	636	ACRES.

Division No. 4

EXCAVATION	1,368,951	CU YDS
CLOSED GRAVITY SECTION	146,160	LIN FT
CONCRETE PRESSURE PIPE	67,666	" "
TUNNEL SECTION	43,770	" "
6 LINES RIVETED STEEL PIPE 48" DIAM	17,186	" "
6 " CAST IRON PIPE, SUBMERGED 60" DIAM	5,820	" "
RESERVOIR LANDS REQUIRED	1,000	ACRES
EARTH DAMS	1,438,000	CU YDS
RIGHT OF WAY	750	ACRES.

Division No. 5

TUNNEL SECTION	12,530	LIN. FT
3-50 INCH RIV. STEEL PIPE	30,590	" "
3-50 " C I PIPE	7,700	" "
3-50 " " " SUB.	20,300	" "

Appendix No. 13

McCLOUD RIVER PROJECT—MT. SHASTA AQUEDUCT

D. P. Doak, Esq., Proponent.

Memorandum by Marsden Manson, City Engineer.

McCloud River as a possible substitute for Hetch Hetchy reservoir was added to the list of sources to be investigated under the order of Secretary Ballinger of May 25, 1910, by a letter of May 11, 1911, from the President of the Board of Engineers, Colonel John Biddle, Corps of Engineers, U. S. A.

Mr. D. P. Doak, the owner of water appropriations and of the lands controlling rights of way for a diverting dam and a conduit to and across Pitt River, was at once communicated with and requested by letter to submit a proposition or propositions setting forth the terms and conditions for the acquisition of his rights and properties by the city.

He expressed his purpose to submit a project by which the cities about the bay could acquire the water rights, the property owned and to be acquired by him for rights of way and for the protection of the supply and to construct all the works necessary to carry out the project. Very general specifications of the required works were furnished him by the City Engineer, and in accordance with these the project has been outlined and submitted, as shown in the following letter from Mr. D. P. Doak to the Board of Public Works.

Proposal to Furnish Water From the McCloud River

San Francisco, December 21, 1911.

To the Honorable Board of Public Works,
of the City and County of San Francisco.

Gentlemen: In compliance with the request of your City Engineer, Mr. Marsden Manson, contained in his letter of June 2, 1911, I beg to advise your Honorable Board, in behalf of myself and associates, that we have completed all necessary surveys, plans, maps and estimates on the Mount Shasta or McCloud River project as a source of water supply for San Francisco and other bay cities, and submit herewith detailed plans and proposition for your consideration.

All plans have been prepared strictly in accordance with specifications furnished by your City Engineer, and call for the highest and most permanent class of construction.

The project contemplates carrying the waters resulting from the melting snows on Mount Shasta, by means of the natural channel of the McCloud River, to a point near its confluence with the Pitt River, where the waters will be diverted into a reinforced concrete aqueduct and carried to San Francisco.

From the diverting dam to a point on the Sacramento River near Anderson, the capacity of the aqueduct is designed for 1200 sec. ft., or 774 million gallons per day. Between the diverting dam and the Pitt River the conduit will be 23 feet wide on top, 20 feet at the bottom, and 6 feet deep, lined with concrete. The crossing over the Pitt River will be a three-span reinforced concrete arch bridge, the conduit, after crossing Pitt River, discharging direct into the tunnel section by a drop in the sub-grade of 5½ feet.

The tunnel of 28,250 feet in length will be in hard rock excavation throughout, but to insure absolute permanency and safety will be lined with concrete.

From the lower tunnel portal the conduit will be 23 feet wide on top, 11 feet wide on the bottom, and 11½ feet deep for about four miles, and from there on to the first power station will be pressure pipe of reinforced concrete and riveted steel.

The first power station will be located on the west bank of Little Cow Creek, about one mile south of Bella Vista, and will have an effective head of 194 feet, developing 26,500 h. p.

The route of the aqueduct thence follows the valley of Little Cow Creek to the crossing of the Sacramento River near Anderson. We have deemed it advisable to maintain the control of the entire 1200 sec. ft. flow up to the crossing of the Sacramento River, and utilize the available head of 42 feet at the Sacramento River for power development from the 800 sec. ft. surplus water, developing 3260 h. p. This brings the surplus just that much nearer when needed.

The crossing of the Sacramento River consists of a reinforced concrete arch, with four spans of 150 feet each in length, with 40-foot flume spans as approaches, the entire length of bridge and approaches being 2500 feet.

After crossing the Sacramento River the route follows generally about a mile west of the river to Red Bluff, and transverses a section of country broken by a series of streams and ridges, and involves the combined use of gravity conduit, reinforced concrete pipe, flume section and tunnels, all designed for a capacity of 400 sec. ft.

Power plant No. 3 is located near Red Bluff, with an effective head of 29 feet.

From Red Bluff to the crossing of Stoney Creek the route traverses a gently rolling country, with several valleys requiring reinforced concrete pressure pipe construction.

The general route south from Stoney Creek parallels the Southern Pacific Railroad about four miles to the west, as far as the west side of the town of Arbuckle. This portion is practically all in level valley land, and includes one section 44½ miles long of reinforced concrete pressure pipe under a maximum head of 95 feet.

From Arbuckle to the crossing of Cache Creek another section of broken, rolling country is encountered, which involves some expensive construction in deep, open cuts, tunnels and flume crossings of numerous stream beds.

From Cache Creek to Suisun the route traverses a section of country sloping gently to conform to the grade of the aqueduct.

From Suisun to the crossing of Carquinez Straits the route crosses the Suisun marsh between the main line of the Southern Pacific Railroad and the branch line to Napa Junction, and then follows close to the edge of the marsh line to the point of crossing Carquinez Straits near Army Point.

The section crossing the upper Suisun marsh will be reinforced concrete pressure pipe under a maximum head of 20 feet.

The marsh lands crossed are now all under process of reclamation, and will be substantially dry and firm in time for the construction of the aqueduct.

The crossing of Carquinez Straits is designed for six lines of submerged cast iron pipe 60 inches in diameter, which will discharge into a receiving tank excavated in rock on Suisun Point.

Directly above the receiving tank will be installed six pumping units, each having a daily capacity of 33,400,000 gallons. These pumps will be of the double suction three-stage type of centrifugal pumps, guaranteed for an efficiency of 75 per cent, and will be directly connected to synchronous motors of 3000 rated h. p. The transmission line will be a three-phase system, carrying 100,000 volts, constructed of stranded copper cables of 000 B. & S. gauge copper wire, supported on modern steel towers and equipped with the latest improved insulators.

An auxiliary steam turbine generating plant of 10,000 k. w. capacity, capable of developing 25 per cent overload, will be added for purposes of emergency in case of interruption in the electrical equipment.

A line of six iron riveted pipes, each 50 inches in diameter and 3¼ miles in length, will connect the pumping plant with the receiving reservoir.

The water surface of this reservoir will be at an elevation 300 feet above city base, and will have a reserve capacity of 2,780,000,000 gallons.

The discharge from the reservoir will be through a series of tunnels aggregating 10½ miles in length, terminating in Berkeley, north of the University of California. The tunnels are designed to operate under the pressure head of a full reservoir, and will have discharge capacity of 400 sec. ft. at low water level of the reservoir.

Supply for San Francisco is provided for by a system of three 50-inch mains, to be laid along the streets of Berkeley and Oakland leading to the water front near the Western Pacific Railroad terminus, and thence by three lines of cast iron submerged pipe, crossing the bay of San Francisco and terminating on the water front of San Francisco at the most favorable point to permit of connecting with the distributing system of the city.

The construction now proposed would give 100,000,000 gallons per day for distribution in San Francisco proper, 100,000,000 gallons to distribute to the cities across the bay, and 50,000,000 gallons to distribute to the cities and inhabitants of the Sacramento Valley, with 524,000,000 gallons more available at Anderson as an additional supply when needed.

The supply of good water for domestic use to the cities and inhabitants of the Sacramento Valley will contribute greatly to its development.

Proposition

For the sum of forty-two million dollars ($42,000,000), to be paid as the work of construction progresses, under proper restrictions to be hereafter agreed upon, we propose to construct and complete in every detail the aqueduct in accordance with the maps, plans and specifications herewith submitted, within four years from the date of acceptance of this proposition, and propose to vest in the City and County of San Francisco absolute rights to divert 1200 sec. ft. of the minimum flow of the McCloud River, together with the power rights on said river capable of economically developing all power necessary for pumping.

We also propose to vest in the city, by good and sufficient title, all necessary right of way for the construction of the aqueduct, all necessary ground for power plants, pumping plants and receiving reservoir. We also propose to acquire and vest in the City and County of San Francisco, by good and sufficient title, all private or corporation deeded lands within the drainage area of the McCloud River above our proposed diverting dam which may be so located or of such a nature as to permit of future development of industries liable to contaminate the water collected upon and flowing from such ownership.

In addition to the above, if this proposition is accepted, we propose to reimburse the City and County of San Francisco for all sums previously expended in the purchase of lands and legally established rights on the Tuolumne watershed, and agree to give the Turlock and Modesto Irrigation Districts an option for a period of ten years to acquire said title and rights, at actual cost to us without interest.

If our proposal is accepted, we further agree to give a good and sufficient bond to guarantee the faithful performance of our obligations, and to protect the City and County of San Francsico against all mechanics' liens or employers' liability.

In the presentation of this project we have endeavored to submit plans and designs of structures that provide for the very best types of construction, and all materials and mechanical appliances are intended to represent the best product of American genius.

We fully realize that our proposal involves the purchase of property that might be avoided, and construction features far in excess of what is required at the present time, and is subject to certain modifications that will tend to materially reduce the amount of the above proposal.

The essential facts to be considered in connection with a municipal water supply are:

(1) The degree of purity of the water, and the probability of its so continuing;

(2) The amount of water available and the assurance of its permanency;

(3) The relative cost of the project and probable rates to consumers.

Quality of Water

The McCloud River water is of unquestioned purity. The source is primarily from the melting snows on Mount Shasta, one of the highest peaks in California, and entirely free from all contamination.

In its descent to the stream it is naturally filtered by seepage through various beds of porous lava and pumice stone, and gushes forth in immense natural springs, nearly as cold as ice. Its large volume, flowing in a narrow rock-ribbed channel, precludes the remotest possibility of any future contamination.

The entire watershed, of approximately 675 square miles, is a wild, mountainous, uncultivated, rocky region, densely covered with underbrush and trees, whose forest growth is of very little commercial value except a small portion at the base of the mountain.

Quantity of Water

There is no stream in California that can compare with the McCloud in its volume of low water discharge per square mile of drainage area. This is due to the natural reservoirs contained in the perpetual glaciers on Mount Shasta and the volcanic and lava formation at the base of the mountain, which absorbs the melting snow like a huge sponge, and gives up the water slowly and with great consistency. The river does not get extremely high or low, and the water never becomes more than slightly discolored after the heaviest storms.

The minimum flow of the McCloud River is over 1200 sec. ft. Stream measurements made by the United States Geological Survey at its Gauging Station established at John's Camp, on the river about fifteen miles above our proposed diverting dam, show the minimum flow of the river to be as follows:

October, 1902	1228 sec. ft.
October and November, 1903	1282 sec. ft.
February and September, 1904	1468 sec. ft.
October and November, 1905	1340 sec. ft.
September, October and November, 1907	1370 sec. ft.
Five days September, 1908	1178 sec. ft.
Balance September, 1908	1228 sec. ft.

Between the proposed diverting dam and the station at John's Camp there are several small streams and numerous springs emptying into the river, which add considerably to its flow.

There is absolutely no conflict of title in any way to our appropriation of the 1200 sec. ft. of water from the McCloud River. There is no part of the McCloud River water, or that of the Pitt River, into which it discharges, that is now used or appropriated in any way, nor is there any need for any part of the McCloud River water for irrigation at any place on the drainage, as the run-off of the other streams tributary to the Sacramento Valley, exclusive of the McCloud, is over 25,000,000 acre feet per year, or more than double the amount necessary to properly irrigate the entire 4,000,000 acres of land in the Sacramento Valley. So there can never be the objections raised that have been urged against the Hetch Hetchy appropriation.

There is no doubt that the use of water for domestic purposes should precede all others. However, the development of the great San Joaquin Valley, as well as the Sacramento Valley, is of the highest importance to San Francisco; and if the city can secure a good and sufficient supply of water that will not interfere with other development, it should do so.

There can be no question that running water in a properly regulated channel is much purer and better than water collected in reservoirs, which must of necessity stand for a year or more before using.

There can also be no question that the water running in the McCloud River, of which we have accurate gauging by the Government for a number of years (showing a minimum flow of over 1200 sec. ft., or 774,000,000 gallons per day), is much safer to depend upon as a source of supply than any storage reservoir system, based, as it must be, on estimates which at best are always uncertain.

The cost of maintaining the system proposed by this project will be extremely low, on account of the non-perishable character of the construction. The cost of operation will be likewise extremely low, as all the electric power required to pump the water to the distributing reservoirs is developed by the project without cost.

The total cost of operating the proposed plant, delivering 250,000,000 gallons per day to the distributing reservoirs, including labor, maintenance, and 4 per cent interest charged on the cost of the entire plant, should not exceed $2,000,000 per year, or a cost of less than 2⅛ cents per 1000 gallons of water delivered. The cost, based on a consumption of 100,000,000 gallons per day, which amount should be consumed by San Francisco, Oakland, Berkeley and other cities to be served by the time the project can be completed, should be less than 5½ cents per 1000 gallons.

The additional water power rights secured by the city with this project will supply ample power necessary to pump any additional supply added to the project, up to the full appropriation of 774,000,000 gallons per day.

The type of construction proposed will permit all materials used, except electrical equipment, to be obtained from home products and manufacturers, and as a result will cause the distribution of all moneys to be paid to home labor instead of to Eastern or foreign firms.

The construction of the Los Angeles aqueduct, which is five miles longer than the one contemplated by our project, was a much greater undertaking for Los Angeles (whose population, at the time the project was started, was less than 150,000) than this project is for San Francisco.

The Los Angeles aqueduct will be finished within the coming year, at a total cost of less than $25,000,000, or well within the estimate, the accomplishment of which is considered to be one of the greatest achievements in the line of municipal work ever undertaken in this country, and which reflects great credit on the administration and the engineers responsible for the same.

The cost of our project is considerably higher than that of the Los Angeles project, by reason of the crossing of the bay and straits with submerged pipes, and the contractors' profit and allowance for risks assumed, which must be included.

Should the city conclude to purchase the property of the Spring Valley Water Company as a distributing system—which we think should be done even at the present valuation (if no better terms can be secured), as the value of the immense land holdings for park purposes would more than compensate for the difference in the actual value of the distributing plant and the purchase price—and the city should conclude that the acceptance of our proposition would be too great an undertaking to assume, the burden could be lightened by the organization of a water district, to be comprised of all the territory to be served.

Respectfully submitted,

D. P. DOAK.

Accompanying Mr. Doak's proposal were drawings traced from the topographic sheets of the U. S. Geological Survey and a crude profile made up from the same. These are reproduced on a preceding page, also various well-finished drawings of incidental structures. Copies of all of these were filed with the Board of Army Engineers, but are not reproduced here. Also, there were several appendices giving comments and description in further detail of several features.

The City Engineer's Comments

The comments of Marsden Manson on the above propositions are in brief as follows:

The advantages of this source, if the project could be carried out as proposed, are

(1) The purity of the water. The control of the water shed as offered.

(2) The constant and reliable discharge of the McCloud River.

(3) Unity and scope of the project and possibility of supplying other cities en route to San Francisco.

(4) Accessibility of all sections of the route.

The prime objections are

(1) Distance and great cost.

(2) Cannot be used in common with sources now owned by the city.

(3) Rights of diversion are not complete.

(4) Exchange of Hetch Hetchy properties not authorized, and possibility of jeopardizing the water rights owned by the city.

(5) Acceptance of such a proposition must rest with the people on referendum and would require a two-thirds vote.

THE McCLOUD RIVER AS A SOURCE OF WATER FOR SAN FRANCISCO.

Memorandum by C. E. GRUNSKY, Consulting Engineer.
June 29, 1912.

The McCloud River has not in the earlier investigations by San Francisco of the possible sources of water been considered as an available source for a municipal supply, because of its remoteness, and because the lack of adequate storage facilities in the river's watershed or anywhere along the route of a conduit from this stream to the bay region.

Furthermore, this source has the objection which applies to all sources of waters north of San Francisco Bay, that the conduit would have to cross the Straits of Carquinez and the Bay of San Francisco. Reliability of service in the case of any such project as one based on a water supply from the McCloud River would not be up to the desired standard.

It may be noted that other than a possible site for a terminal reservoir in the hills back of Martinez and two reservoir sites owned by the Peoples Water Company on Pinole Creek and San Pablo Creek which, at about 300 feet above sea, have a combined capacity of about 17 billion gallons, such localities as afford the necessary capacity in the trans-bay section are either too far off a direct conduit line or are at too great an elevation to come into serious consideration. Any McCloud River project should therefore be considered as one on which neither the storage which is desirable to safeguard the quality of an unfiltered water nor the storage which is desirable to safeguard the continuity of service can be secured without large additional expense.

It will be seen from the results of an inspection of the gathering ground of the McCloud River waters on the volcanic slopes of Mount Shasta by Mr. C. E. Grunsky, Jr., herewith submitted, that there is considerable human activity in this region and this activity is likely to continue. When the timber on private lands is all cut, there will be more to be obtained from the Shasta National Forest, and there will, in time, be new growth on the lands already cut over. There will always be some grazing, too, and always some summer population. While it might seem possible that the land in private ownership, some 300,000 acres, might all be acquired by the city and that the city, in co-operation with the United States Government, might so police the watershed that the water of the McCloud would continue as safe drinking water. But this is only remotely probable, and so long as adequate storage can not be pointed out it should be regarded as an essential requirement that the McCloud River water be filtered before delivery to San Francisco.

Even at the low stage of the river, when its flow is all supplied by springs, the water near Baird is not entirely clear, but where seen in deep pools has a milky appearance. It is not as inviting at Baird as the crystal clear water of the upper stream near Bartles or the water of the high mountain streams of the Sierra Nevada.

The gaugings of the stream made by the United States Geological Survey indicate that the McCloud rarely carries less water than about 1100 second feet. This may be accepted as the minimum, but there are many seasons when the flow does not fall below 1200 second feet. Some extracts from the records are presented in the memorandum of Mr. Grunsky, Jr., already referred to.

There seems to be no doubt that the natural flow of the stream would meet San Francisco's requirements in so far as quantity is concerned.

In any event, the diversion should not be the full flow of the McCloud River even at its lowest stage; some water should be left in the stream, or returned to it, within a short distance of the diversion after use for power.

The power generated at one or more power stations would be transmitted to pumping stations of which one would probably be located on the conduit line near Martinez and another in San Francisco.

It is to be assumed that the headworks would be so located that the full amount of power required to effect a delivery of water in San Francisco at an elevation of about 175 feet above mean sea level would be secured. Considerably more power can probably be made available if the headworks are located up stream from Baird, but on this point no positive information is at hand.

Any diversion at or below Baird would have to be practically the entire low water flow in order that power development may be worth while. Even then the power secured by a possible drop of about 1200 second feet near Cow Creek, and a surplus of 600 second feet at the Sacramento River, *would not be fully adequate to meet the ultimate requirement of raising the remaining 600 second feet to the height of about 300 feet, which would be desirable somewhere near Martinez.*

The right to divert water, subject to prior rights on the stream, would have to be acquired under the laws of California; and it would probably be necessary in addition thereto to obtain an authorization by Congressional action, as the McCloud River is tributary to the navigable waters of the Sacramento River and the ultimate depletion by possibly 620 second feet of the Sacramento River, which enters Sacramento Valley with a flow at lowest stages of only little more than 4000 second feet, would necessarily have some effect upon its low water stages. If it could be shown to be necessary this Congressional authorization could no doubt be secured; but so long as other sources are equally available it might be difficult to secure recognition of the necessity.

Conduit Route

The diversion would probably be made on the east bank of the McCloud River by tunnel. The Pit River would be crossed by tunnel and the Gray Rocks would be pierced by tunnel about 5 miles long. Concrete conduit, either cut and cover or pressure conduit, or both, and steel pipes would lead to a power house on Cow Creek. Here all the water would be dropped possibly 194 feet as indicated in the Doak project, and the surplus could either be returned to the river through Cow Creek or carried 11 miles farther to the Sacramento River. In the latter event some additional power could be secured with the surplus water at this point. A power station at the river would, however, have to be planned with due regard to the river's high stages and could not be expected to add materially to the power output.

From here to Red Bluff the line could be upon either side of the Sacramento River and the location would be generally in rather rough country, but in a formation which appears favorable for tunneling and makes the best type of conduit attainable at reasonable cost.

Below Red Bluff the route would necessarily be across the drainage lines which descend from the Coast Range. Red Bank, Elder, Thoms and other creeks would have to be crossed, and the rolling land between them would at various points have to be deeply cut into. The broad channel of Stony Creek would also have to be crossed, probably a short distance westerly from Orland. Thence on a course bending out a little to the west from a due north and south line, the route would be over favorable ground, generally smooth surfaced and easily excavated, to some point near Arbuckle, where the conduit could either be put through a tunnel 3 or 4 miles long to Hungry Hollow or could be carried nearly at grade around the eastern base of the hills which here extend far easterly to the north side of Cache Creek.

The crossing of Cache Creek, and some miles further south the crossing of Putah Creek, would offer no difficulties. Suisun would be reached with a pressure conduit of concrete under a low head, and the route would thence be around the edge of the Suisun marsh by way of Cordelia and along the base of the hills at the west of the marsh to the north shore of the Straits of Carquinez.

The depths of water in these straits on a mud bottom are not too great to make a crossing with pipes impracticable. It is to be assumed, therefore, in the absence of any information that would permit of passing on a tunnel scheme, that the crossing would be made in pipes. These would probably be 36 inches or more in diameter, enough being used to supply the water to the pumps at Martinez up to their capacity.

Nearly all of the conduit line from the north side of Stony Creek to the Straits of Carquinez would be pressure conduit. A location on a fairly direct line for the same can readily be found such that no point thereof would be under a greater head than 70 feet. Reinforced concrete pipe of large diameter would be the type of conduit best suited to this section of the aqueduct.

Somewhere near Martinez there would be a filtering plant. This would be of the simplest type, as the water to be filtered is naturally quite free from sediment, and the filters could be operated at a high rate.

The filtered water would be pumped into force mains to some point at an altitude of about 300 feet, where a small reservoir could be constructed from which the flow would be by tunnel and steel pipes through the mountains east of Oakland and across the east bay region to Alameda, about as described in the Hazen report for his suggested Mount Diablo route.

It has not been thought necessary to go further into the details of a McCloud River project, and no very definite idea of probable cost can be given. This would depend largely upon the final profile of the line, which has not been surveyed by the city.

Some idea may, however, be obtained by a comparison with the probable cost of such a project as outlined in the Doak proposition.

The estimates of quantities as submitted by Mr. Doak have been revised; the length of line has been checked and consideration was given to the fact that materials for concrete are not everywhere conveniently available. Thus at the McCloud River sand would probably have to be supplied by crushing rock. For long stretches of the line in the Sacramento Valley gravel or rock for concrete would have to be hauled, probably from Stony Creek gravel beds by rail and then from the nearest railroad station to the work by team.

Tunneling may be assumed to be in rather favorable material on the part of the line above Red Bluff, and in the hills west of Arbuckle but considerable allowance for uncertainties should be made for tunnels between Martinez and Oakland.

The Proposal of Mr. Doak

The length of the conduit as proposed by Mr. Doak would be about 235 miles. The intake at McCloud River would be at an elevation of about 740 feet. About 224 feet of this elevation is to be consumed in generating power; the rest would be available as fall for the conduit. At the south side of the Straits of Carquinez the water would be barely above sea level and would there, as already explained, be raised by pumps to the height necessary to put it through the tunnels and pipes under the bay to San Francisco.

In comparing this project with others, the fact should not be lost sight of that elevation at which water is delivered in San Francisco has value. This as a first approximation, subject to revision, may be noted at $50,000 for each foot to which 200,-million gallons of water per day are raised or fifteen million dollars for 200 million gallons daily raised 300 feet. It is believed that the elevation of the reservoir near Martinez, shown at 300 feet, would be adequate to effect a delivery of the water in San Francisco at about 150 feet.

There is submitted in connection with the notes of Mr. C. E. Grunsky, Jr., already referred to, a tentative estimate of the cost of constructing the McCloud River project as outlined by Mr. Doak, but with a number of minor modifications. This estimate was made before base prices were adopted for comparative estimates of various projects and is therefore to be regarded as subject to revision.

C. E. GRUNSKY,
Consulting Engineer, Water Supply Investigation.

NOTES ON THE McCLOUD RIVER PROJECT

By C. E. Grunsky, Jr.
June 29, 1912.

Introduction

These notes are based on information gathered on a recent trip into the McCloud River catchment area and along the proposed conduit line from the dam site to San Francisco.

The watershed was examined at the points which could be most conveniently reached. The McCloud River itself was examined at a point near Bartles, at the Hearst summer home near the mouth of Mud Creek, and near the mouth of the McCloud from Baird to its junction with the Pitt River.

Photographs were taken on the trip through the watershed and the dam site below Baird, mentioned in the Doak proposal to the city, was inspected. The projected conduit line as indicated in this proposal was then followed as closely as the existing roads permitted by automobile from the selected point of diversion as far as Orland, and again from Dunnigan to the crossing at Putah Creek.

No actual survey of the final line proposed has been made, either by the proponent or by the city, with the exception of that portion of the line lying between the Sacramento River crossing near Anderson and Red Bluff for a distance of about 40 miles, of which the results of a survey have been furnished by Mr. Doak. A preliminary line had been layed out and surveyed from the McCloud River dam site to Suisun, but this line was based on the use of a 150-foot dam on the McCloud River with a shorter tunnel through the Gray Rocks just south of Pitt River than is now proposed and a conduit down Stillwater Creek Valley with a different arrangement of power stations. After the survey was made the entire system of pipes, conduits and power stations as at first projected was changed. The crossing of the Sacramento River near Anderson has not been surveyed and, *with the exception of the short stretch mentioned from the Sacramento River to Red Bluff, the location is a "paper" location*, based, however, in part on the very reliable information found upon the large scale maps of the west side of Sacramento Valley prepared by the United States Geological Survey.

No borings or explorations have been made at the dam site, tunnel sites, or stream crossings, so that the estimates of the cost of the project must be based mainly on the information obtained from these United States Geological Survey maps and inspection and general knowledge of the country through which the conduit line passes.

The large tracings furnished to the city by the proponents of the upper portion of the feasible canal route *are enlargements by pantograph from the Government maps, and show no more detail than the small maps from which they were drawn.* The final profile as furnished by proponents is necessarily based, therefore, largely upon information from these maps, except only as already stated. For some 23 miles from the south portal of the Gray Rock's tunnel to the Sacramento River crossing *it is based on the 200-foot contours of the small scale Red Bluff quadrangle, which interval (200 feet) in a more or less broken country is very unsatisfactory for the estimate of cut and fill along a gravity section conduit.*

The difficulty of making an estimate of the cost of the project as outlined is apparent. The main reliance must be placed on a knowledge of the country crossed and allowance must be made for the unforeseen difficulties not indicated by the data furnished.

Location and Extent of the Catchment Area

The area included in the McCloud drainage area lies south and east of the summit of Mount Shasta. It comprises an area of about 675 square miles, including the southeast slope of Mount Shasta, with large areas of valuable timber and grazing land. Small portions are available for the purposes of cultivation, but these areas are not large and the agricultural interests are not of great importance and are at the present time almost wholly undeveloped.

Geology

The geology of the watershed is somewhat complicated by numerous foldings and intrusions of igneous rock. The surface of the rock is characterized by the presence of large areas of volcanic tuffs and lavas of more or less porous nature in the vicinity of Mount Shasta and other extinct volcanoes and cinder cones. The region also contains areas of limestone and crystalline schists, and the remains of a sheet of Cretaceous sandstone, shales and conglomerates. The lavas and tuffs are intermingled with the sedimentary rocks and both types of formation are cut by intrusive dykes and masses of igneous rocks. The geology of the lower portion of the watershed is described in detail in the Redding folio of the United States Geological Survey.

McCloud River and its Tributaries

The McCloud River is about 40 miles long, rising in the vicinity of the town of Bartles, about 20 to 25 miles southeasterly from the summit of Shasta. It has a very light flow for some distance, but in the vicinity of Fowler's Falls at Big Springs the drainage from the snow covered area on the southeasterly slope of Mount Shasta comes to the surface in many large springs, greatly augmenting the flow in the river. Because of the porosity of the lava and tuff mantling the slopes of Mount Shasta, very little of this melted snow water flows over the surface of the ground, but the main portion finds its way underground through the porous volcanic material until it is brought suddenly to the surface near the river. Mud Creek is one stream that has its source on the slope of Mount Shasta and which carries some of the melted snow water on the surface to the river. At the time it was visited (June, 1912) Mud Creek was considerably discolored by suspended volcanic matter and the McCloud was somewhat milky in appearance and had a slight earthy flavor. At Bartles, near the source of the river and near the eastern edge of the catchment area, the river water was clear as crystal. On a visit to the mouth of the McCloud River this same milkiness or opalescence was observable. The river water at the United States Fish Hatchery near Baird had a slight earthy taste and was opalescent when looking through it to any depth. In a glass it seemed perfectly clear and the taste was not sufficient to destroy its value as drinking water.

The main tributary to the McCloud River is Squaw Creek, which rises near the summit of Mount Shasta and flows southward past the town of McCloud, having a length of about 20 miles. There are numerous other small tributaries, some named and some not named, many of these flowing on the surface for only a small portion of the year.

Stream gaugings have been made from time to time by the United States Geological Survey, but the records are not continuous. On September 9, 1901, Mr. S. G. Bennett, Assistant Hydrographer of the United States Geological Survey, gauged the McCloud River at a point one-fourth of a mile above the United States Fish Hatchery at Baird, finding a flow of 1096 second feet. In October, 1910, Mr. W. W. Hardy of the United States Geological Survey measured the McCloud River at the railroad bridge near the mouth and found a flow of 1100 second feet. These are the lowest records found in the United States Geological Survey reports. Continuous records of water elevation were kept at John's Camp, at the foot of Hirz Mountain, about opposite Gregory, from 1902 to 1908, and the lowest flow estimated during that period was 1178 second feet for several days in the middle of September, 1908.

A gauging station was established at Baird, about one-fourth of a mile above the Fish Hatchery, during December, 1910, and continuous gauge readings have there been taken since that time. The lowest recorded discharge at this new gauging station is 1243 second feet on January 4 to 8, 1911.

From these records it is apparent that a safe assumption for low water would be 1100 second feet instead of 1200 second feet, as claimed by Mr. Doak.

The extreme known maximum flow of the river probably occurred on February 2, 1881, when the river rose to 26 feet above the low water mark, washing the United States Fishery away (see page 2 of the Redding folio, United States Geological Survey). On March 16, 1904, the river rose to a gauge height of 14.5 feet and was probably carrying over 45,000 second feet at that time. (The rating curve has not been extended beyond 12.0 feet.) On March 19, 1907, the gauge read 12.0 feet, indicating a flow of 30,000 second feet.

The river is discussed in the Redding folio, which was issued April, 1905, and may be quoted as follows:

"The McCloud River is usually lowest in September, just before the rains begin. Mr. Livingstone Store of the McCloud Fishery reports 9 feet of rain and a rise of the river to 26 feet above the low water mark on February 2, 1881, when the Fishery was washed away. Rises of 15, 16 and 20 feet are not uncommon. The height of the river varies from day to day even in the dry season. The oscillations are related to the rate of melting of the Mud Creek glacier on Mount Shasta, for within 12 to 20 hours after a particularly warm interval the McCloud rises at the Fishery and is clouded with light colored sediment like that coming from glaciers."

A river of such violent freshets as above referred to will be muddy and discolored during the rainy season. It cannot be assumed that this water would at all times be fit for delivery direct to the consumer. Any McCloud River project should make some provision for adequate storage before use or for filtration.

No storage facilities in adequate amount appear to be available near the source of this water, and near San Francisco they are not as large as would be desirable. The reservoir above Martinez which is suggested as a feature of the project has not been surveyed. It is possible that with a dam about 145 feet high, somewhere near 3,000,000,000 gallons of water could be there stored.

The stream flow, so far as indicated by the records, is given in the following tables:

DISCHARGE MEASUREMENTS

On McCloud River, at John's Camp (drainage area=608 miles), opposite Gregory, 6 or 7 miles north of Fish Hatchery.

Date.	Gauge, height, ft.	Discharge, sec. ft.	Remarks.
1902—October 8-9	1.3	1,228	Low water during two days.
1902—September 23	1.45	1,272	Measurements by S. G. Bennett.
1903—September-November	1.40	1,282	Low water for 24 days.
1904—September	1.70	1,468	Low water for 14 days.
1904—October 30	1.75	1,600	Measurement by O. W. Peterson.
1905—October and November	1.50	1,340	Low water for 19 days.
1906—December 5-8	1.50	1,340	Low water for 4 days.
1907—September-December	1.55	1,370	Low water for 62 days.
1903—March 29	7.20	11,870	High water for year.
1904—March 16	14.50	Probably	over 45,000 sec. ft. high water for year.
1905—January 22	8.05	14,280	High water for year.
1906—March 31	7.40	12,400	High water for year.
1907—March 19	12.0	30,000	High water for year.
1908—January 20	4.95	6,170	High water for year.

DISCHARGE MEASUREMENTS

On McCloud River, near Baird, California.

Date. Measurements.	Hydrographer.	Width, feet.	Area of sec. sq. ft.	Mean velocity, sec. ft.	Gauge, height, feet.	Discharge, sec. ft.	Remarks.
1901—September 9	Bennett	107	658	166.	—	1,096	One-fourth mile above Fish Hatchery.
1910—October 17	Hardy	100	244	4.51	—	1,100	Made at railroad bridge.
1910—December 22	Wood	150	696	1.90	2.13	1,320	Made from boat 100 feet below gauge.
1911—April 1	Peckham	172	1,260	3.39	5.02	4,270	Made from boat 100 feet below gauge.
1911—May 23	"	162	1,090	2.99	4.57	3,260	Made from boat 100 feet below gauge.
1911—September 27	"	155	940	1.35	2.00	1,270	Made from cable at gauge.
1912—January 25	Lee	190	1,940	4.77	8.00	9,260	
1912—March 10	"	155	1,160	2.06	3.59	2,390	Soundings very accurate.

DISCHARGE MEASUREMENTS
ESTIMATED FROM GAUGE READINGS AND RATING CURVE.

On McCloud River, near Baird, California.

Date. Measurements.	Hydrographer.	Width. feet.	Area of sec. sq. ft.	Mean. velocity, sec. ft.	Gauge. height, feet.	Discharge. sec. ft.	Remarks.
1911—January 4		—	—	—	1.91	1,243	Low water for five days.
1912—January 3-4		—	—	—	1.95	1,255	Low water for two days.
1911—March 7		—	—	—	9.40	12,640	High water for year.
1912—January 26		—	—	—	8.50	10,450	High water to date.
1912—June 9		—	—	—	2.53	1,560	Date of visit of C. E. Grunsky, Jr.

Population

The catchment area of the McCloud River has a summer population of over 2000 people. The only towns within the watershed worthy of notice are McCloud, Bartles and Baird. McCloud is by far the largest of the three, having a population of 1500 to 2000 during the summer months. The town is owned by the McCloud River Lumber Company and is occupied mainly by its employees. It has a complete water and sewage system, the sewers discharging into a septic tank about 60 ft. x 15 ft. x 6 ft. in size. The effluent is conducted by a wooden flume to a point about half a mile below the town, where it is discharged into an open ditch and is then used for the surface irrigation of the cultivated fields in Squaw Creek Valley.

Bartles is the present terminal station of the railroad and is a small town of 15 or 20 inhabitants. The railroad has been continued beyond this station to lumber camps on the slope of Black Fox Mountain.

Baird is located near the southern extremity of the watershed, where the United States Fish Hatchery is located. Its population probably is less than that of Bartles.

Quite a large floating population is found in the lumber camps, over 300 men being engaged in felling the trees and cutting them into logs. The cutting continues from April to October and the logs are brought to McCloud by railroad and are worked into lumber by two large lumber mills having a combined capacity of about 250,000 board feet daily.

There are numerous summer homes located along the river. Some of these are built of stone and most of them are located right on the river bank. Two fishing clubs have clubhouses on the river and because of the scenic beauties of the McCloud gorge and the demonstrated fishing possibilities of the stream the number of pleasure seekers will always be large during the summer.

The agricultural interests are of minor importance, as has already been stated, but the water power possibilities of the McCloud River are evident when we note that the river falls 450 feet in 21 miles of its length, or at an average rate of 21 feet to the mile. Power locations have been made on the river, but to the present date no actual power has been generated.

Livestock

Upon inquiry at the office of the Southern Pacific Company, the information was obtained that grazing contracts have been let for an area of about 75 square miles, extending over a total range of 120 square miles. (The latter figure includes the Government land lying between the railroad company's sections.) The assistant land commissioner of the Southern Pacific Company, Mr. F. W. Houtz, states that a much larger area of the watershed is used for grazing purposes.

The United States Forest Service states that during the fiscal year 1910-1911 permits were issued for the grazing of 5711 cattle, horses and hogs, and 9186 sheep and goats, making a total of 14,879 head in the Shasta National Forest Reserve, which has an area of about 2500 square miles. About 250 square miles of this reserve lie within the McCloud watershed and in the lack of better information it may be assumed that a proportional number of these graze upon the lands of the reservation that lie within the watershed. On this basis there would be about 1500 head of live stock on reservation lands within the watershed a part of each year. In addition, some stock grazes on the privately owned lands not included in the forest reserve, but no data has been obtained bearing on the number of head.

The demand for mountain grazing land is bound to increase because of the encroachment of agricultural interests on the foothill grazing regions, and this watershed, therefore, is and will remain a region of considerable interest to owners of stock.

Effect of Constructing the Dam

The construction of a dam to raise the water about 40 feet above low water at the dam site thus far considered, near the mouth of the McCloud River, will back the water up to the Hatchery. The racks would have to be removed and the site of the buildings would be subjected to greater danger of inundation than at present, as it is hardly conceivable that a dam 40 feet high, a short distance below the Hatchery, would not have a material effect upon the high water stage of the river at Baird.

Even in the present unobstructed condition of the stream, the site of the Hatchery is not entirely free from menace by the high waters. The water of the McCloud River occasionally in the past has carried away the racks and has flooded the ground on which the buildings stand. This was notably the case at the high stage in February, 1881.

The removal of the Fish Hatchery to some other point, and probably to some other stream, would no doubt be the result of the construction of a dam at the point which has been tentatively selected by Mr. Doak and to which his water rights apply.

The lower portions of the watershed are sparsely covered with small pine, some oak and other trees and brush. The timbered areas are higher up on the slopes of Mount Shasta. There are in the neighborhood of 100,000 acres of timber land in the watershed, outside of the Shasta National Forest reservations, and on this area large amounts of timber have already been cut, but there is still much timber standing, and the lumbering activities will no doubt be continued for many years into the future.

Attention should be called to the fact that the McCloud River furnishes about 14 to 15 per cent of the mean flow of the Sacramento River as measured at Jelly's Ferry, and its low water flow at John's Camp is equal to 35 to 40 per cent of the low water flow of the Sacramento River at the same point.

Jelly's Ferry is some distance above Red Bluff and is about 35 miles north of the intake works of the Sacramento Valley Irrigation Company, which contemplates, without any storage, the irrigation of 225,000 acres of land in the Sacramento Valley. A diversion of 300 to 600 second feet from the McCloud would undoubtedly embarrass this project and would probably cause a shortening of the period during which irrigation would be permitted by the United States Army Engineers, who are in position to control because of the navigability of the Sacramento River.

A FIRST APPROXIMATION TO COST OF THE McCLOUD PROJECT

McCLOUD RIVER PROJECT OF D. P. DOAK ET AL. ESTIMATE OF COST.

By C. E. GRUNSKY, JR.

DIVISION NO. 1.

		Estimated Cost
Diverting Dam and Headworks Length 226 ft.; depth 57 ft.		$125,000
Open Gravity Conduit (Dam to Pitt R. Crossing) 1300 linear ft. @ $16.40		21,320
Pitt River Crossing Shafts and Tunnel		75,000
Tunnel No. 1 under Gray Rocks with two 400 ft. shafts and 12 in. lining 28,250 linear ft. @ $77.00		2,175,250
Covered Gravity Conduit (Tunnel No. 1 to Cow Creek) 23,000 ft. @ $22.80		524,400
Reinforced Concrete Pressure Pipe (10 ft. 6 in. diameter), 17,800 ft. @ $33.50		596,300
Steel Riveted Pipes (11 ft. diameter) 4,000 lin. ft. @ $40.00		160,000
Power Station No. 1 (Effective head—195 ft. Theoret. h. p.—26,500)		400,000
Poles, Lines and Wiring 196 miles @ $5,000		980,000
Closed Gravity Conduit (Cow Creek to Sacramento River Crossing) 56,000 ft. @ $20.00		1,120,000
Reinforced Concrete Pressure Pipe 7,000 ft. @ $33.50		234,500
Power Station No. 2 (Eff. head—42 ft. Theoret. h. p.—3800)		66,000
Reinforced Concrete Pressure Pipe		
450 ft. @ $33.50	$15,100	
300 ft. @ $30.00	9,000	
Also 300 ft. concrete trestle @ $20.00	6,000	
		30,100
Sacramento River Crossing (Four 150 ft. arched spans with 50 ft. abuttments and 300 ft. of approaches), complete		231,400
Pressure Pipe (10 ft. 6 in. diameter)		
8,850 ft. @ $33.50	$311,600	
350 ft. @ $30.00	10,500	
Also 300 ft. trestle @ $20	6,000	
		328,100
Closed Gravity Conduit (excavation taken from profile) 116,700 lin. ft. @ $22.80		2,660,800
Concrete Flumes 14,720 lin. ft. @ $25.00		368,000
Tunnels (Concrete lined) 19,100 lin. ft. @ $50.00		955,000
Concrete Pressure Pipe 18,580 lin. ft. @ $30.00		557,400
Power Station No. 3 (Eff. head—29 ft. Theoret. h. p.—1315)		22,500
Total		$11,631,070

DIVISION NO. 2.

Reinforced Concrete Pressure Pipe 230,000 lin. ft. @ $33.50	$7,705,000
Concrete Flumes 4,220 lin. ft. @ $25.00	105,500
Closed Gravity Conduit 74,480 lin. ft. @ $20.00	1,489,600
Total	$9,300,100

DIVISION NO. 3.

Closed Gravity Conduit 208,210 lin. ft. @ $20.00	$4,164,200
Reinforced Concrete Pressure Pipe 40,080 lin. ft. @ $30.00	1,202,400
Concrete Flume 17,480 lin. ft. @ $25.00	437,000
Tunnels (Concrete lined) 19,350 ft. @ $50.00	967,500
Total	$66,771,100

DIVISION NO. 4.

Closed Gravity Conduit 146,160 lin. ft. @ $20.00	$2,923,200
Reinforced Concrete Pressure Pipe 67,666 lin. ft. @ $30.00	2,030,000
Tunnel (Concrete lined) 43,770 lin. ft. @ $50.00	2,188,500
Riveted Steel Pipes (48 in. diameter) 103,116 lin. ft. @ $10.00	1,031,200
Cast Iron Pipe (Submerged—36 in. diameter) 9 lines 5820 ft. long @ $600.00	3,492,000
Pumping Station (300 ft. lift—200 mil. gal. capacity)	960,000
Reservoir Lands 700 acres @ $150.00	105,000
Earth Dams (Reservoir near Martinez) 1,438,000 cu. yds. @ $0.50	719,000
Total	$13,448,900

DIVISION NO. 5.

Tunnels (Concrete lined) 12,530 lin. ft. @ $50.00	$626,500
Riveted Steel Pipe (50 in. diameter) 91,770 lin. ft. @ $11.00	1,009,500
Cast Iron Pipe (50 in. diameter) 23,100 lin. ft. @ $20.00	462,000
Cast Iron Pipe (Submerged—36 in. diameter) 9 lines 20,300 ft. long @ $600.00	12,180,000
Total	$14,278,000

SUMMARY OF COSTS.

Division No. 1	$11,631,070
Division No. 2	9,300,100
Division No. 3	6,771,100
Division No. 4	13,448,900
Division No. 5	14,278,000
	$55,429,170
15 per cent for engineering and ordinary contingencies	$8,314,370
Grand Total	$63,743,540

Note: Excavation was included in the unit costs of conduits.

This cost estimate is not based strictly upon the plans of the project as submitted to San Francisco by Mr. Doak, with his proposal to turn over to the city a completed system.

Instead of a bridge crossing Pitt River, a tunnel under the river was assumed.

The amount of excavation that will be required along the line was estimated at a somewhat higher figure than noted by Mr. Doak.

The concrete tunnel lining was taken at an average thickness of one foot.

The reinforced concrete shell of the pressure conduit in Sacramento Valley would probably be prescribed at one foot instead of nine inches and has been so assumed.

The crossings of the Straits of Carquinez and of the Bay of San Francisco are figured for this estimate for the full capacity of 200,000,000 gallons per day, on practically the same basis as indicated in the report of Mr. Allen Hazen on a supply of filtered water from Sacramento River. This is not in exact accord with Mr. Doak's proposition, who proposes to bring only one-half of the water to the San Francisco side of the Bay and suggests the use of pipe of a diameter of fifty inches instead of thirty-six inches. It is believed that any bay crossing for so large an amount of water, as here assumed, would be made in tunnel rather than in a series of pipes and that the cost of such a tunnel upon full investigation of all conditions would be found to be materially less than the cost of a crossing as here indicated.

The estimate does not include water rights, rights of way, nor the acquisition of several hundred thousand acres of land privately owned in the watershed which it might be found desirable to own in case of the selection of this source of supply.

Neither has the cost of a filtration plant been added, concerning the probable cost of which reference is made to the Hazen report.

C. E. GRUNSKY, Jr.

COMMUNICATION RELATING TO WATER RIGHTS.

(Letter addressed to the City Attorney by C. E. Grunsky, Consulting Engineer.)

San Francisco, June 27, 1912.

Mr. Percy V. Long,
City Attorney,
San Francisco, Cal.

Dear Sir:

Replying to your inquiry of June 26, relating to the proposition of Mr. Doak to furnish McCloud River water to San Francisco, which inquiry is, in the form of a memorandum prepared by Mr. English of your office, I present the following for your information and guidance.

It is found that the following notices of the appropriation of water from the McCloud River have been posted by Mr. Doak or by an agent for him.

On December 8, 1910, a notice was posted for Mr. Doak at a point on McCloud River N. 40° E., 1350 feet distant from the quarter section corner on the south line of Section 27, T. 34 N., R. 4 W., M. D. B. & M. in the County of Shasta. The amount of water claimed under this notice is

> "that I claim all the water now flowing or which may hereafter flow to the bedrock of said McCloud River at said point of diversion to the amount of seventy-five thousand (75,000) miners inches, measured under a 4-inch pressure, or fifteen hundred (1500) cubic feet per second flow."

This water was claimed

> "for the purpose of mining, manufacture and as motive power for turning machinery of all kinds, and more especially electrical machinery now or hereafter to be constructed in a power house for electrical development, located 200 feet below where this notice is posted."

On the same day, December 8, 1910, at the same point, a second notice was posted for Mr. Doak, under which 10,000 miners inches of water, measured under a 4-inch pressure, or 200 cubic feet per second, were claimed and the notice states

> "that it is my purpose and intention that said waters shall be used for irrigation and for public purposes, including the sale, rental and distribution thereof to counties, cities and counties and cities and towns in the State of California and to the inhabitants thereof for municipal, domestic and any and all lawful and beneficial uses, and that I do appropriate said water for sale and distribution for said uses."
>
> "It is my intention to divert and convey the said waters by means of ditches, flumes, tunnels and pipes to the valley and on the foothills along the said McCloud River and through the counties, cities and towns lying adjacent to and on both sides of the Sacramento River in the State of California."

On the 4th day of January, 1911, notice of an appropriation was posted for Mr. Doak at a point on the McCloud River N. 20° E., 1050 feet from the south-west corner of Section 11, T. 34 N., R. 4 W., M. D. B. & M., and the amount of water claimed thereunder was

> "all the water now flowing or which may hereafter flow to the bedrock of said McCloud River at said point of diversion to the amount of seventy-five thousand (75,000) miners inches, measured under a four-inch (4") pressure, or fifteen hundred (1500) cubic feet per second flow."
>
> "I claim said water for the purpose of mining, manufacture and as motive power for turning machinery of all kinds, and more especially electrical machinery now or hereafter to be constructed."

It is stated in the notice that the place where the water is to be used is

> "on the right bank of McCloud River, 200 feet below this notice."

On March 23, 1911, notice was posted by Mr. Doak at a point on the McCloud River N. 70° E., 1050 feet from the southwest corner of Section 11, T. 34 N., R. 4 W., M. D. B. & M., and claim was made to

> "20,000 miners inches, measured under a 4-inch pressure, or 400 cubic feet per second flow of the water now flowing in the bed of the McCloud River * * *"

The purpose of this diversion as stated in the notice is

> "that said waters shall be used for irrigation and for public purposes, including the sale, rental and distribution thereof to counties, cities and towns in the State of California and to the inhabitants thereof for municipal, domestic and any and all lawful and beneficial uses, and that I do appropriate said water for sale and distribution for the said uses."
>
> "It is my intention to divert and convey said water by means of ditches, flumes, tunnels and pipes to the valley and on the foothills along said McCloud River and through the counties, cities and towns lying adjacent to and on both sides of the Sacramento River in the State of California."

This notice was recorded on March 27, 1911, in the records of Shasta County.

On December 18, 1911, a notice was posted for Mr. Doak at a point on the McCloud River N. 40° E., 1350 feet from the quarter section corner on the south line of Section 27, T. 34 N., R. 4 W., M. D. B. & M., and under this notice claim was made to

> "Sixty thousand (60,000) miners inches, measured under a four-inch (4") pressure, or twelve hundred (1200) cubic feet per second flow of the water now flowing, or which may hereafter flow in the bed of the McCloud River."

It is stated in the notice

> "that it is my intention and purpose that said water shall be distributed and sold for domestic and municipal purposes to cities, cities and counties and cities and towns in the Sacramento Valley and at and near the Bay of San Francisco in the State of California and to the inhabitants thereof for municipal and domestic uses and irrigation and that I do appropriate said water for sale and distribution for the said uses."

Except as noted in the case of the notice posted on March 23, 1911, there is no information, at present, in this office relating to the date on which these notices were recorded.

The last of these, being a claim for 60,000 miners inches, or 1200 cubic feet per second is apparently to be considered as the basis for title to the water which Mr. Doak proposes to deliver to the City of San Francisco.

By inspection and inquiry on June 19, 1912, an assistant on the San Francisco water supply in this office, Mr. C. E. Grunsy, Jr., learned that *the only construction work on the project was the building of a broad trail or road from the railroad bridge which crosses the McCloud River just north of Pitt River, for a distance of about 100 yards up the west bank of the McCloud, on which road he learned at that time one man was kept at work. No one was seen on this work at the time of the inspection.*

The proposed diversion of water which, according to the proposition of Mr. Doak, amounts to 1200 second feet, is practically all of the low water flow of the river, as will appear from the following information taken from the published records of the U. S. Geological Survey. These measurments apply to a point 6 or 7 miles above Baird:

> On October 8th and 9th, 1902, for two days the discharge of McCloud River is entered in the records at 1228 second feet.
>
> On September 23, 1902, a gaging by Mr. S. G.

> Bennett, of the U. S. Geological Survey, showed a flow of 1272 second feet.
>
> In 1903 for 24 days the discharge was as low as 1282 second feet.
>
> In September 1904, for 14 days the river fell to a low water discharge of 1468 second feet.
>
> On October 30, 1904, the flow was gaged by Mr. O. W. Peterson of the U. S. Geological Survey and 1600 second feet were then flowing in the river.
>
> In 1905 the lowest flow was 1340 second feet.
>
> In 1906 the lowest flow was 1340 second feet.
>
> In 1907 the lowest flow was 1370 second feet.

Later measurements and estimates were made by the U. S. Geological Survey near Baird and the following relating to the low water stages at that point may be noted:

> On September 9, 1901, the river was gaged by Mr. S. G. Bennett, an assistant in the U. S. Geological Survey, at a point one-quarter mile above Baird. The discharge of the river at that time was 1096 second feet.
>
> On October 17, 1910, another gaging by an assistant, Mr. Hardy, of the U. S. Geological Survey, showed the discharge of the river at that time to have been 1100 second feet, this measurement being made at the railroad bridge.
>
> On December 22, 1910, the flow was 1320 second feet as measured by Mr. Wood of the Geological Survey.
>
> On September 27, 1911, another measurement at the low stage of the river was made by Mr. Peekema, the flow of the river at that time being 1270 second feet.
>
> In 1911 for five days in January the river had a flow of 1243 second feet.
>
> On January 3rd and 4th, 1912, its discharge was 1255 second feet.

The project as submitted to the city by Mr. Doak would decrease the natural flow of the Pit River and of the Sacramento River down to near Anderson by 1200 second feet. This is about one-third of the low water flow of the Pit River at its junction with the Upper Sacramento and is about one-fourth of the natural low water flow of the Sacramento River down to Anderson where, under the proposed project, 800 second feet, after use for power development, are to be returned to the stream.

Below Anderson, or more precisely at a point some three miles below the Anderson bridge over the Sacramento River, the reduction of the natural flow would be 400 second feet and this reduction would apply to all parts of the river below that point. This reduction amounts to about 9 per cent of the river's ordinary low water flow at Red Bluff, where the river enters the Sacramento Valley.

The Sacramento River, in its course through the Sacramento Valley, is navigable. That the withdrawal of considerable amounts of water would in some measure affect its navigability at low stages is apparent from the following letter addressed to the City Engineer by Major S. A. Cheney, in response to an inquiry relating to the effect upon the river's navigability of a withdrawal of 600 second feet. Major Cheney is a member of the California Debris Commission, being United States Engineer Officer in charge of the river work in California.

> San Francisco, June 9, 1911.
>
> Replying to your letter of June 8th, in regard to the effect of the diversion of 600 second feet of water from McCloud River for power, water supply and irrigation purposes, I have the honor to inform you that in my opinion such diversion would materially impair the navigability of the upper Sacramento River during low water stages.
>
> The act of Congress under which the Sacramento Valley Irrigation Co. (successors to the Central Canal and Irrigation Co.) is operating, limits the amount of their diversion to 900 second feet when the river is at a 2-foot stage or under, and provides that the diversion of water may be carried on only when it does not seriously injure navigation. The opinion has been expressed by my predecessor and concurred in by the Chief of Engineers that the diversion of 900 second feet of water by the Sacramento Valley Irrigation Co., when the river is at or about the average low water stage, will be to the injury of navigation, the effect becoming noticeable at a stage about one foot above average low water. The intake of the Sacramento Valley Irrigation Company is below that portion of the river in which we have the most trouble to maintain an adequate channel. It seems certain therefore, that the direct diversion of 600 second feet from the McCloud River would seriously impair the navigability of the upper Sacramento during low water stages.
>
> I do not mean to state, however, that the interests of navigation are or should be the controlling ones in this case. It has generally been considered, I believe, that city use should take precedence over navigation use of stream waters, the latter in the general case taking precedence over the irrigation use of the same.
>
> In view of the several interests involved and their importance, it would seem necessary to apply to Congress for authority to carry out the proposed project.

The Act of Congress, referred to in the foregoing letter, was approved May 9, 1906. Under this Act the Central Canal and Irrigation Company * * * * and its successors are granted the right to divert at all seasons of the year, from the Sacramento River, * * * * "while and so long as such diversion shall not seriously injure the navigation of such river, an amount of water, which at a stage of said river of two feet above low water, as determined by the United States Engineer in charge of the improvements of said river, or at any lower stage, shall not exceed nine hundred cubic feet per second, to be used for irrigating the lands of the Sacramento Valley on the west side of the Sacramento River * * * *."

The rights granted by this Act are made subject to cancellation by the Secretary of War after 15 years without any further Act or procedure on the part of the United States, as to such portion of the waters as are not then applied to beneficial use.

The point at which the proposed diversion from the McCloud River would be made, under the Doak proposal, is located on the McCloud River south of and below the limits of the Shasta National Forest Reservation, and no rights of way through any portion of the National Forest would be required to make the McCloud water available for San Francisco.

It is to be noted that in addition to the work done on a road by Mr. Doak, at the point of proposed diversion, surveys were made by him for a conduit route as far down as Suisun, but that *the route as surveyed conforms for a short distance only to the conduit location as shown on the maps furnished this office by him and as made the basis of his proposal.*

Very truly yours,
(Signed) C. E. GRUNSKY,
Consulting Engineer.
Water Supply Investigation.

Curtis H. Lindley. Henry Eickhoff.
LINDLEY & EICKHOFF.
Counselors at Law.
604 Mills Building.

San Francisco, June 28, 1912.

McCLOUD RIVER PROJECT.

Hon. Percy V. Long,
City Attorney,
San Francisco, Calif.

My Dear Sir:

I have been requested by your office to formulate for presentation to the Secretary of the Interior and the Advisory Army Board, acting under his direction, a criticism from a legal standpoint of the project submitted by David P. Doak, known as the Mount Shasta, or McCloud River project, which purports to be a plan for supplying the City of San Francisco and other cities along the route of a proposed aqueduct with the water from the McCloud River in Shasta County, California.

From an inspection of the papers submitted to me, Doak claims the following rights:

1. Ownership of riparian lands along the McCloud and Pitt Rivers, below the point of proposed diversion.
2. A right to divert 1200 second feet of the water of the McCloud river and conduct it to the City of San Francisco and other cities for domestic, irrigation and municipal purposes.
3. Appropriative rights to 1500 second feet for power purposes.

As the ownership of riparian lands gives no right to divert the water out of the watershed or to apply it to any purpose except upon the land riparian to the stream, I do not consider it a factor in the project. It affords a measure of protection against injunctions restraining diversion, but confers no rights to the use of the water except for purely riparian purposes.

The appropriations for power purposes may also be eliminated from consideration. To some extent, power might be useful for construction purposes, but the City of San Francisco is not authorized by its charter to deal commercially with hydro-electric power.

With reference to the appropriation of 1200 second feet, it is not claimed that any of this water has ever been diverted, or that there has been any work done looking to the construction of a diverting dam. I am advised by the City Engineering Department that the only observable work that has ever been done looking to a diversion of the water showing "due diligence" is a few hundred feet of road construction and survey of a line to Suisun, which has since been in the main part abandoned.

The latest notice of appropriation filed and recorded by Doak is dated December 18, 1911. It is under this notice that he claims 1200 second feet. A prior notice claiming 400 second feet was dated March 23d, 1911, but only claimed the right to conduct the water to the Sacramento Valley. The law under which these notices were posted and recorded requires that within sixty days after the notice is posted the appropriator (unless it is a municipal corporation) must commence the excavation or construction of the works in which he intends to divert the water or the survey road or trail building necessarily incident thereto, and must prosecute the work diligently and uninterruptedly to completion.

The report of the engineers of the City will, I think, clearly demonstrate that the work done by Doak is merely perfunctory, not commensurate with the magnitude of the undertaking and has not been prosecuted with such diligence as the law contemplates. The date of the last water locations (December 18, 1911) considered with reference to this investigation and the controversies over the city's efforts to obtain water from the Tuolumne sources, is significant.

The proposed diversion would take all the water of the McCloud River at certain seasons of the year. The measurements of the Geological Survey, shown upon page 7 of Doak's printed proposition, establishes a minimum flow during a period from 1902 to 1908, varying from 1468 second feet to 1178 second feet. Data obtained by the City Engineering Department indicates a somewhat lower minimum. The McCloud River is an important tributary to the Sacramento. While, for the time being, Doak proposes to turn into the Sacramento River

800 second feet, he still claims the right to divert this whenever its use becomes necessary. The effect of the elimination of this quantity of water on the navigation of the Sacramento, is referred to in a letter dated June 9, 1911, written by Major Cheney of the U. S. Engineering Corps, member of the California Debris Commission, which is on file in this proceeding. It seems apparent that the Government would never permit this water to be diverted except as suggested by Major Cheney through an Act of Congress.

Recurring to the claimed right to divert the water, the only muniment of title which Doak has or claims to have, arises out of the posting and recording of a notice of appropriation. This notice is simply the initial step in a series. It confers no right to the water. It performs the sole function of giving priority as against subsequent appropriators. No right to the water arises until there is an actual diversion and use, and the right is then measured not by the amount claimed, but by that actually diverted and used for a beneficial purpose.

This rule is too well settled to require the citation of authorities.

Doak's proposition shows upon its face that he has nothing in esse to sell. It is all in posse. It is a purely speculative scheme upon its face. He proposes to acquire water and land in the drainage area of the McCloud River. There is no assurance that he will ever acquire either.

It would seem to me that the City of San Francisco should not in its efforts to secure a water supply be compelled to consider schemes of this speculative, uncertain and intangible character.

What adverse rights to the diversion of this water exist can only be ascertained by a hydrographic survey of the McCloud, Pitt and Sacramento Rivers. A mere assertion that none exist could not be accepted as the basis of the most ordinary transaction involving the purchase of water rights. It cannot be possible that the City of San Francisco should be compelled to surrender its rights in Cherry Creek and Lake Eleanor and Hetch Hetchy and be forced to deal with a project which is involved in so many uncertainties as the one under consideration.

The suggestions hereinbefore made can, I think, be more fully developed in the course of your oral presentation of the matter to the Secretary of the Interior and the Army Board at the final hearing.

Sincerely yours.

(Signed) CURTIS H. LINDLEY,

Special Counsel for the
City of San Francisco,
in re Water Supply.

McCLOUD RIVER PROJECT.

STATEMENT BY JOHN R. FREEMEN, CONSULTING ENGINEER.

San Francisco, Cal., June 29, 1912.

Percy V. Long, Esq.,
City and County Attorney
of San Francisco, Cal.

Dear Sir:

I have considered the McCloud River as a source of water supply for the cities about San Francisco Bay in two aspects, first that of the proposition submitted by David P. Doak and associates; and second, that of a source available to the city for development by its own means and forces.

Regarding Mr. Doak's Proposition

Mr. Doak describes his project in a printed "proposition to the City and County of San Francisco on the Mt. Shasta or McCloud River project," etc. This is dated San Francisco, December 21, 1911, and signed by D. P. Doak. The printed pamphlet contains also a supplemental report signed by Clement H. Miller, Chief Engineer, chiefly relative to the purity and capacity of the source and the requirements of the cities about San Francisco Bay.

The Crudeness of the Proponents' Maps

Mr. Doak and Mr. Miller have also submitted for our examination a collection of prints from maps and photographs comprising a vague small-scale map of his proposed aqueduct line and an equally vague small-scale profile, which contains a statement of estimated quantities of structural material, etc. Also a photographic print of the plan and cross-section of the proposed dam and head works, of the bridge and conduit for crossing the Pit River, of the tunnel sections, of the open cut section, of the bridge and conduit across the Sacramento River, a general section of pressure pipe and flume design for 24 feet span, another for 40 feet span, an outline of the arrangement of power house No. 1 and plan of the proposed receiving reservoir, holding about ten days' supply, near the pumping station at the Carquinez Straits, and an outline design for a pumping station.

These plans are mere outlines, largely of a diagrammatic or explanatory character, but are sufficient for present purposes, save in the need of a larger scale map of the aqueduct line covering some definite location so that the cost of tunnels and the crossing of creeks, ravines, and swamps can be approximated and some proper allowance be made for difficulties of location. Experience shows that in general a thousand feet of aqueduct built upon a hydraulic grade line along an undulating surface actually costs very much more than would be estimated from an ideal section on a paper location.

Much of the Route Not Yet Surveyed

On making personal inquiry of Mr. Clement H. Miller, Chief Engineer of the project, for his location maps, it is learned that only a small part of the line had been definitely located in the field and that the only maps available for by far the greater portion of the line are the lithographed sheets published by the U. S. Geological Survey. An instrumental survey, chiefly a simple stadia traverse with levels, is said to have been made for the upper forty miles out of the total aqueduct length of 230 miles; but even for this distance the project has since been changed and an entirely different system proposed. The important crossing of the Sacramento River near Anderson has not been surveyed, nor have any borings been made at dam sites, tunnel sites or other stream crossings, nor we are not informed that any competent geological study has been made at the site of the tunnels, certain of which form a very difficult and uncertain feature of the project.

A simple inspection of the topographic map shows that the McCloud source requires the longest aqueduct of any that are being considered. That it starts out at so low an elevation as to require great pumping stations near the city for which power must be provided, and that with its crossings of the Sacramento River, the Carquinez Straits and particularly the long crossing beneath San Francisco Harbor, it presents grave liability to interruption and consequent water famine.

Moreover, it is dangerous to take a running stream as a source of water supply unless either filtration works are included, or a provision made for a large detention reservoir, holding at least a month's supply.

The Proponent Underestimates the Cost

From an examination of Mr. Doak's plans and from personal conference with Mr. Doak and his chief engineer, Mr. Miller, I am satisfied that the proposition of Mr. Doak to build and turn over to the city an aqueduct of 250 million gallons daily capacity over such ground as is shown by the maps of the U. S. Geological Survey and his own outline plans, cannot properly be considered seriously until more surveys and plans have been made. I have examined the estimates of cost prepared by Mr. Grunsky, which I believe are about as low as can reasonably be made with safety on such extremely crude data as Mr. Doak presents, and these estimates of cost present further proof that Mr. Doak and his associates are simply deceiving themselves from inexperience in the construction of large aqueducts and that they cannot possibly make good their promises.

I am confirmed in this judgment by my experiences as a member of the engineering board which prepared the preliminary estimates of cost for the Los Angeles aqueduct, and from that as Consulting Engineer to the Board of Water Supply of New York in its explorations, covering many miles of aqueduct line, and from many other studies of water supply projects.

Secondly, the McCloud River as a Source Available to the City

It may be assumed that if this source were readily necessary or desirable, the City of San Francisco or the group of cities about San Francisco Bay, could obtain by purchase or by acts of Congress, by permission of the Department of Agriculture, and otherwise, the water rights, lands and rights of way necessary for diverting the requisite amount of water from the McCloud River for supplying either 200 million gallons daily or 400 million gallons daily; but although all of these lands, water rights and rights of way were to be tendered to the City without cost, it is plain they would be less desirable than the Tuolumne sources.

The McCloud source has the following disadvantages:

Quality of Water Demands Safeguards

(1) Any practicable point of diversion of the waters of the McCloud River lies downstream from numerous lumber camps and downstream from the town of McCloud, which contains a population of over 1500 to 2000 people during the summer months, and the smaller towns of Bartells and Baird. The purpose of the national forest is to conserve their resources and ultimately to cut the ripe trees, and for an indefinite future the region is certain to be one of much human activity, although in the first cutting perhaps three-fourths of the privately owned lands have already been logged off. At the present time I happen to be acting as Consulting Engineer in a situation where on the shores of a lake which serves as the source of water supply to a certain city, there are temporarily employed less than half the number of lumbermen commonly said to be engaged within the proposed McCloud watershed, and although these men are all concentrated in two camps and closely watched, it is found difficult to maintain full and efficient sanitary precautions.

Much professional experience in tracing the relation of typhoid fever to water supplies makes it plain beyond the shadow of a doubt that it would be dangerous to the health of the citizens of San Francisco to divert the water of the McCloud River and take it directly through aqueducts to the bay cities without detention in large reservoirs for a sufficient period to kill off any pathogenic germs. A single careless case of "walking typhoid" on the shores of the river might become a serious element of danger, and either a large storage and detention reservoir or a system of filtration must be provided as a part of this project in order to make it comparable in the sanitary way with the proposed Hetch Hetchy system, which takes water out from large reservoirs in a sterile, unpopulated watershed and delivers it into storage reservoirs at Crystal Springs or Lake Chabot (or a projected San Antonio reservoir).

Source Plainly Vastly More Expensive Than Hetch Hetchy

(2) A simple inspection of the map serves to show that this McCloud source must of necessity be vastly more expensive than the Tuolumne source, when size of aqueduct for delivering 400 million gallons daily to the cities is considered, and when the added cost of filtration and pumping are also included. The courses of the necessary power for pumping must be carefully considered, both in its relation to cost and in its possibilities of interruption, if use is made of electric power brought from a distance.

The amount of electric power that could be generated from the waters of the McCloud River under appropriations or diversion to power sites the same or similar to those proposed by Mr. Doak, would be insufficient to lift this large volume of 200 million gallons, or later of 400 million gallons to the level necessary for efficient service in the cities. The losses of energy involved in the turbines, the electric generation, conversion, transmission and re-conversion to the proper working potential, together with the loss of efficiency in pumps requires a power drop of about three times the head against the pumps if only the same quantity that is pumped is used for power near the source; and all of this electrical apparatus and hydraulic machinery is expensive to install and the added expense to maintain in comparison with the Hetch Hetchy source, which will flow by gravity into the highest levels of the Crystal Springs reservoir and Lake Chabot even after these have been raised many feet above their present height.

Danger of Interruption to Service

This matter of electrical transmission from power station nearly 200 miles away to the pumps near the Carquinez Straits and possibly to other pumps within the city limits, presents grave possibilities of interruption to the supply by a breakdown in the electrical transmission line or by a burning out of the insulation by lightning or other accident in either power station or pumping station, though all ordinary precautions be taken to build these of fireproof materials, whereas in the Hetch Hetchy project all such questions may be avoided and very ample reservoir storage provided on the way to the city as an additional safeguard or to give opportunity for inspection and repair on the aqueduct line.

Moreover, this McCloud source, like all of the other northern sources, involves the disadvantage of crossing first the Carquinez Straits and second, the difficulties and expense of crossing beneath the broad area of lower San Francisco Bay, and also tunneling the difficult and uncertain rock formations of the Coast Range between Antioch and Berkeley, which we can probably almost entirely avoid by the extreme southern location that has been selected under expert geological advice for the revised aqueduct route from Hetch Hetchy.

No Opportunity for Water Power as on Hetch Hetchy

Although the city under its charter has no right to engage commercially in the manufacture and sale of power and although the present plans for the development of the Hetch Hetchy do not provide for hydro-electric development in the immediate future, the opportunity is carefully conserved for developing from this water very large amount of power in case the city should desire it in the near or distant future for municipal purposes or as an aid to agriculture by pumping, or for any other purpose. Although this power asset may rest undeveloped for a long time, it must not be lost sight of in measuring the comparative advantages between the Tuolumne source and the McCloud source.

Respectfully submitted,

(Signed) JOHN R. FREEMAN,
Consulting Engineer.

Appendix No. 14

EEL RIVER AS A SOURCE OF WATER FOR SAN FRANCISCO

By C. E. GRUNSKY, Consulting Engineer.

July 31, 1912.

Eel River has been suggested as a possible source of water for San Francisco. This river has not in the past been seriously taken into consideration because the conduit route is not favorable, or rather, because the direct conduit route and the one generally assumed as a feature of this project would cross the Golden Gate. The location of a conduit under the Golden Gate ruled out this project from study in 1901. It was, in the light of more available sources, classed as non-available at that time and is not covered by the writer's progress report of that year.

The same conditions obtain today even though more is now known of the quantity of water that can be made available at a point from which the water could by gravity flow, in a conduit under comparatively light pressure be brought to San Francisco.

The Snow Mountain Water and Power Company

The studies that have been made by the engineers of the Snow Mountain Water and Power Company indicate that on an area of the river's watershed of 326 square miles which their works command, aided by a storage reservoir not yet constructed, an ultimate development of about 200,000,000 gallons of water per day can be made. This, in so far as quantity is concerned, might be worth while. Of this water some now being used for power is carried out of the watershed of Eel River just as it would have to be for a San Francisco supply and is dropped, after generating power, into Russian River.

The power company, as will be seen from this statement, is in control of the situation on Eel River, and it should be assumed that such rights as the City would have to acquire would prove expensive.

But it is also apparent that there is no serious difficulty in the way of affecting the diversion of water from Eel River—and after generating power therewith—bringing the same in closed conduits down the valley of the Russian River and thence following quite closely the alignment of the Northwestern Pacific Railroad Company's tracks, reaching the northerly shore of the Golden Gate somewhere near Lime Point, where a bay crossing would have to be made.

Some Project Features

A water supply project from Eel River would involve storage of water in large quantity not alone to equalize the season's flow, but to hold over water from the seasons of large runoff for use in those in which the natural stream flow is deficient. The storage site which is available is at Gravelly Valley. Here with a dam of reasonable height (about 150 feet of impounded water) about 206,000 acre feet of water can be stored.

Gravelly Valley commands about 268 square miles of the watershed of Eel River which is tributary to the diverting tunnel of the Snow Mountain Water and Power Company. The remaining 58 square miles are below any fair sites for storage. If, therefore, the filtration feature of a project is to be eliminated, it would be necessary to take water out of a reservoir at Gravelly Valley and carry the same in a covered conduit to the power house. This would mean about 12 or 13 miles more of conduit above the power house near Potter Valley than at present in use. It is understood that from the present diverting dam in Eel River to Ukiah, the length of aqueduct would be about 25 miles.

From Ukiah to San Francisco the conduit would have a length of approximately 110 miles. The total length of a conduit, therefore, based on the supposition that the water be taken out of the river at Gravelly Valley, should therefore be estimated at about 148 miles.

The ultimate yield of the 326 square miles tributary to the diverting works of the power company are, as above stated, if supplemented by storage, capable of yielding 200 million gallons of water per day.

This includes the runoff from the 58 square miles of watershed below Gravelly Valley. If these were cut out to insure the quality of the water, the reliable limit of the water production of Eel River would be cut down somewhat, probably to 170 million gallons of water per day.

It seems probable in the light of present information that the economical utilization of the available fall from the Snow Mountain power house to San Francisco, 1014 feet, would lead to a delivery of water at the northerly bay shore near Lime Point at sea level. Consequently in comparing this project with other projects, which would make delivery at 175 to 200 feet above sea level in San Francisco possible, account should be taken of the capitalized cost of pumping the water through a sub-bay conduit with the same altitude of City delivery. A project which thus includes a pumping system would have the advantage of keeping the conduit under relatively light pressure. Moreover, the fall would thus be used to best advantage in reducing the conduit dimensions.

But an alternative project is equally feasible. The water can be conveyed in steel pipes under comparatively high pressure from the power house to San Francisco and delivery can be made without pumping at any desired elevation up to about 300 feet above sea level.

No study has been made to determine which of these projects has the greater merit, although as stated it seems probable that the one involving pumping will be the more economical.

Quality of Water

No examination has been made by the City of the quality of Eel River water at or near Snow Mountain. But in view of the fact that storage in large amount, about 206,000 acre feet or 65 billion gallons, in a reservoir at Gravelly Valley, the construction of which has been under contemplation for some time by the Snow Mountain Water and Power Company, would be a feature of any municipal project and that the storage in such a reservoir would safeguard the quality of the water, it may be preliminarily assumed that water from this source would come into use without filtration.

General Remarks

No cost estimate of this project can be offered at this time. There are too many uncertainties relating to project features at the upper end and there is the uncertainty of making a crossing under the Golden Gate.

If such a project were carried out it would have the disadvantage of being a supply without any nearby storage. It would, therefore, take low rank in the matter of reliability of service.

It has been suggested at various times that it would be possible to bring Eel River water to San Francisco by a longer route than the one herein referred to, crossing the Straits of Carquinez and the Bay of San Francisco by way of Goat Island and tunnel or by way of Alameda Point on the route described in the report of Mr. Allen Hazen on a filtered supply from Lower Sacramento River.

The location of what would probably be the conduit route by way of Golden Gate is shown on a small scale map and there is also shown on a separate sheet a profile of the Northwestern California Railroad, with an extension, from map data, to and across Golden Gate.

C. E. GRUNSKY,
Consulting Engineer.

Note—Two plans accompanied this report which are not reproduced here. Copies were attached to each of the three copies of this report placed on file with Advisory Board of Army Engineers.

Sheet No. 1 Showed a provisional aqueduct route.

No. 2 Showed profile and hydraulic gradient.

Appendix No. 15

SAN FRANCISCO WATER SUPPLY INVESTIGATION—FEATHER RIVER PROJECT

Report by C. E. GRUNSKY, Consulting Engineer,

Assisted by N. A. ECKART, Assistant Engineer, Water Supply Investigations.

(The following is an abstract of a report filed in triplicate with the Advisory Board of Army Engineers on San Francisco Water Supply, on August 1, 1912, with a few additional notes.)

July 31, 1912.

Comparison With Sacramento

The Feather River discharges into the Sacramento about 65 miles above Rio Vista, the point of diversion proposed by Mr. Hazen for a filtered water supply. There can be no good reason for making the aqueduct this much longer unless water of better quality can be secured or cheapening of operation gained by avoiding the pumping at Rio Vista and Antioch required in the Hazen project, by taking the water at a greater elevation where it issues from the mountains.

In order to gain any marked advantage over the Sacramento River water, so far as quality is concerned, the diversion from the Feather River would have to be made at a point well above the mouth, where the pollution consequent to population and human activity, constantly increasing with time, is a minimum.

Favorable conditions in this regard do not obtain below Oroville, and even above Oroville they are not all that might be desired, as will be shown. Above that town the character of the country changes rapidly, becoming rugged and mountainous, and more or less prohibitive of any large growth of population in the future, except perhaps in some of the large mountain meadows, where stock raising and dairying are now carried on.

The elevation of the river at Oroville, according to the U. S. Geological Survey sheets, is something over 100 feet, so that if the diversion were made there the nearest point at which the quality of water may be considered to be materially superior to the Sacramento River, it would still be necessary to pump all the water to San Francisco, approximately 100 miles farther than from Rio Vista.

The North Fork Most Advantageous

In order to gain sufficient elevation to consider the Feather River project as a gravity supply, it is necessary to go some ten miles further up the stream. About 6 miles above Oroville the waters of the Middle and South Forks join the North Fork, and since the North Fork presents by far the largest and most regular summer flow, that would be the branch to consider.

This North Fork is fed by a remarkable group of springs upstream from Big Meadows which come from deep beds of lava and volcanic ash. Moreover, this natural minimum flow of about 400 or 500 million gallons daily is soon to be supplemented by the construction of one of the largest storage reservoirs in the world, for power purposes at Big Meadows, about 225 miles from San Francisco, on the North Fork.

Turbidity and Possible Pollution

During the winter and early spring the river is swollen from heavy rains, and at this time carries a large quantity of suspended matter. Later in the season another period of high water is caused by the melting snow in the mountains, but at this time a much smaller proportion of suspended matter is carried and the water is of better quality.

Inquiry in regard to the water supply at Oroville brought out the fact that the main supply for that town is drawn from the West Branch of the North Fork, and that while this is considered of better quality than that in the main river there still is much complaint at times owing to the color and turbidity.

The conditions on the water shed affecting the sanitary quality of the water may be stated briefly:

The broad mountain meadows furnish excellent grazing and stock raising is one of the principal industries. The mountain slopes are comparatively heavily timbered and subject to extensive lumbering; practically the whole drainage basin of the North Fork is in a National Forest Reserve and will be worked out under Government restrictions in the future.

These necessary lumber camps, as is the case with all construction and other temporary camps, will offer one of the greatest menaces to the purity of a supply diverted from the running stream, as it is almost impossible to so enforce the sanitary regulations as to eliminate all possibilty of the pollution of the stream.

This region is at present being exploited by the Western Pacific Railroad Co. as a region for summer outings and as a game country, and there is no doubt that with its excellent scenery and climate there will eventually be quite a large summer population.

The population of Plumas County, according to the last census, is 5,259,—the area of the county being 2,694 miles. The area of the watershed tributary to the proposed point of diversion is 2,263 square miles, and as the principal towns are located within this drainage basin, it is evident that there must be approximately 5,000 inhabitants in the area.

Treatment of the Water

The turbidity of the water, particularly during the rather extended periods of heavy runoff, aside from possibility of contamination from human and animal sources, either at the present time or in the future, necessitates some treatment of the water before it may be used for water supply. There is no doubt that with filtration the water would be of good quality; it is also believed that if sufficient storage capacity could be provided so that the water, after collection from the basin, would be held a period of some thirty days or more, it would not only be relieved of the matter carried in suspension, but also the destruction of such pathogenic germs as might be borne therein, would be effected and the necessity of filtration plant would be removed.

These considerations at once suggest for comparison with the project for filtering Sacramento water from Rio Vista as in the Hazen project, two possible projects for water from the North Fork of Feather River, the one with filtration and practically no storage, or very little, along the conduit line, and the other with storage which can, if the maps of the U. S. Geological Survey may be relied upon, be found in the hills back of Martinez. Cost estimates have been made for both of these projects although, as will be explained, only may data have been available as a basis for estimating volume and cost of storage possibilities.

Requirements for Irrigation

In order to be considered available as a source of municipal supply to San Francisco the project must be shown to be capable of development to meet the future demands of the Metropolitan District after first meeting all reasonable future local requirements for irrigation.

The present and future demands on these waters are indicated by data collected principally from reports of the Department of Agriculture, Commerce and Labor and the U. S. Geological Survey, by Mr. A. E. Chandler for Mr. C. E. Grunsky, from which it appears that:

The only existing diversion from the Feather River below Oroville worthy of comment is the Butte County Canal covering about 80,000 acres, about 20,000 of which were irrigated in 1909. The Feather River Canal Company has commenced construction of another canal for the purpose of diverting water at a point about two miles below Oroville. This canal when completed, must remain the high line canal on the west side of the Feather. These two systems, when completed as projected, will cover about 200,000 acres. This area includes practically all of the irrigable land south of the Feather River Canal Company's proposed canal between the Feather and Sacramento Rivers.

Owing to a proposed Yuba River project (the Hotle project) contemplating the irrigation of some 70,000 acres lying north of the Yuba and east of the Feather, it is not probable that any large diversion will be made from the east side of the Feather.

So far as plans have been published, or can be foretold from the map, the area to be irrigated by the Feather River in the Sacramento Valley will not exceed 200,000 acres. On a liberal basis of 1 second foot per 100 acres this would require a maximum diversion of about 2,000 cubic feet per second which for the present may be considered the total future local demand on the waters of the Feather.

The Great Western Power Company which is now building the Big Meadows dam for power purposes is known to have some views as to the use for irrigation of the million acre-feet of storage which this will contain and which so far as resulting from their conservation of flood waters they will own. These views and plans are not fully worked out.

The requirements of the Metropolitan District about San Francisco, will, for the purposes of this report, be considered ultimately amounting to 400 million gallons per day, or 618 cubic feet per second.

Stream Flow

The U. S. Geological Survey has maintained a gauging station at a point just above Oroville since 1902. Records have been kept at Big Bend for a number of years.

There can be no question that the flow past the diversion would always be sufficient to meet a San Francisco requirement of 618 cubic feet per second, or 400 million gallons daily, save for the demands of irrigation, which will ultimately require far more than the minimum flow.

Storage

The minimum flow at Oroville in the published record was 1,100 second feet in September, 1910, but it has been much lower. This year, 1912, as early as July the discharge of the North Fork had fallen to 900 second feet, and on

August 7th was only 770. The mean flow for August, 1912, will probably not exceed 800 second feet.

This minimum flow will soon be greatly augmented by storage in the Big Meadows Reservoir of the Great Western Power Company, which is to contain 1,150,000 acre feet and intended to tide over several years of low rainfall by the release of water stored in years of large rainfall.

It is possible, too, that this reservoir may be used for supplying other power plants to be built off the main line of the North Fork, so that its discharge will not be governed solely by requirements for uniform flow at Big Bend. In such case possibly the total flow at Big Bend may often be no greater than the 2,000 second feet estimated above as probably necessary for irrigation, but this constant flow of about 2,000 second feet will be discharged at Big Bend winter and summer, and doubtless there can be found opportunity for storage in the foot hills, which while not attractive for domestic water supply, would conserve the water for irrigation to the extent that it could be arranged to always divert the amount required for San Francisco from the river immediately below the power house at Big Bend.

The ownership of the power company in the stored water and its right of controlling the delivery would make it necessary to work out some definite agreement between the Metropolitan Water District and the Power Company, which it may be assumed will be feasible, altho at considerable cost.

In order to meet, in addition to San Francisco requirement, a future demand of 2,000 second feet for irrigation below Oroville storage will be necessary.

Purification by Filtration or Storage

Considering then that the sufficiency of the supply is established, providing terms are made with the Great Western Power Company for obtaining the benefits of their storage, and that the quality of the water may be made satisfactory either by filtration or by adequate storage, after diversion from the river, it now becomes necessary to ascertain the possibilities of securing the required capacity reservoir for a detention at any point along the conduit storage.

The storage period necessary to effect the destruction of the pathogenic germs varies with different waters and conditions. In the case under consideration, it is believed that thirty days' storage capacity, at least, should be provided. For the project developed to 200 million gallons daily, this requires 6 billion gallons storage.

There is no reservoir site of this size available near the diversion point, nor is there any along the conduit route at an elevation suitable for use in connection with a gravity supply. In the foothills back of Martinez there are two branches of the Arroyo del Hambre which seem to afford storage possibilities. A study has been made of these and the capacity figured as shown in Table I.

The reservoir sites owned by the Peoples Water Company on Pinole Creek and on San Pablo Creek would serve if their ownership did not interfere.

Capacity of the Arroyo del Hambre

TABLE I.

CAPACITY OF THE ARROYO DEL HAMBRE RESERVIORS NEAR MARTINEZ.

(Estimated from the U. S. Geological Survey Maps.)

	West Branch.			East Branch.		
Contour.	Area, sq. ft.	Volume between contours, 1,000's.	Volume available above 250 cu. ft.	Area, sq. ft.	Volume between contours, 1,000's.	Volume available above 250 cu. ft.
175	......	.....	......	271,200	.....	......
200	......	.....	......	2,109,700	29,761	......
225	874,030	10,920	......	3,948,000	75,721	......
250	1,868,600	34,283	......	6,148,000	126,200	......
275	6,630,500	106,240	106,240	8,650,000	184,970	184,970
300	13,532,000	252,030	358,270	11,815,000	255,800	440,770
	13,532,000	403,473	358,270	11,815,000	672,452	440,770

Combined Quantities

Evaporation surface 580 acres.

Capacity effective for purification, about 8 billion gals.

Storage available for reserve supply, about 6 billion gals.

Total watershed, 6,125 acres.

The flood line of these reservoirs as indicated in the table would be at elevation 300 feet above mean sea level (to which it would have to be pumped). The low water limit or head for delivering through the conduit to San Francisco is 250 feet, subject to friction losses en route.

A most desirable feature in connection with the storage system of purification, in the case under consideration, would be the added factor of safety to the continuity of supply afforded by this considerable storage, located in proximity to the bay region.

Delivery of Filtered Water by Gravity Compared with Pumping to a Detention Reservoir

Ignoring the question of storage in the foot hills or along the conduit route, it would be possible to divert the water from the Feather River at a point below the power station of the Great Western Power Company, conveying it thence in suitable conduit to a point where the natural conditions

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In a reservoir holding 30 days' supply it is by no means probable that the circulation would be so perfect that all the water would be detained 30 days in passing.—J. R. F.

are most favorable for the location of a filtration plant, from which plant, after being filtered, it would again flow in closed conduit to San Francisco, where it would be delivered at an elevation of about 20 feet above sea level. This will be referred to as a Gravity-Filtration project, although the water would require pumping after reaching San Francisco.

The alternative plan suggested is with the same head works, delivering the water by gravity to a pumping station located near Martinez, from which station it would be pumped into the storage reservoirs above referred to at an elevation 300 feet above sea from which it would then flow to San Francisco and be delivered unfiltered under a head of approximately 200 feet. This will be referred to as the Pumping and Detention project.

The main elements of difference between these two propositions of Mr. Grunsky affecting the cost of construction and operation briefly are that in the gravity scheme, which purifies by filtration, the pumping station with its operating cost is absent at Martinez, together with the cost of the reservoirs and dams near Martinez. Offsetting this in the Martinez pumping proposition, where sanitary protection is sought by storage in large terminal reservoirs, the filtration plant is eliminated, and the water is delivered in San Francisco under practicaly 200 feet greater head, and the cost of conduit from Las Plumas to Martinez is materially reduced by using a steeper hydraulic gradient, decreasing the effective head on same.

In order to draw any definite conclusions as to which proposition is the more desirable it has been necessary to make an estimate of cost both of construction and operation for each of the two schemes.

The Gravity Filtration Proposition

Hydraulic Gradient.—The elevation of the dam crest would be 430 feet above mean sea level; the elevation of the discharge at San Francisco is assumed to be 20 feet, giving a total fall of 410 feet in 158.5 miles. In order to keep the bay crossing within the practicable and economical limits of four 36-inch pipes, it was necessary to allow a slope of $S=.002$ for this portion of the work; for the tunnels and light pressure pipe a grade of .0004 was selected, using all the surplus head in the pressure siphon in order to keep the size and weight of the heavier pipe at a minimum. The profile Sheet 2 shows the gradient used in the different parts of the system.

Tunnels.—The tunnels are all designed for a capacity of 200 million gallons per day and it is assumed that all will have a lining of concrete 12 inches thick. For estimate purpose the equivalent of a 10-foot circular section has been adopted. This, with $n = .013$ in Kutter's formula and $s = .0004$ will discharge 336 second feet or a margin of about 8 per cent, which is narrow.

Steel Pipe.—All steel pipe has been figured as double lap riveted on the straight seams and single riveted on the round seams, fabricated from flange steel having an ultimate strength of 55,000 lbs., using a factor of safety of 4 and 70 per cent efficiency of joints.

It is probable that if riveted pipe were used all plate 7/16 inch or heavier would be butt strap; the saving effected would not be material, however, except, perhaps, in the very large diameters and heavy plate.

The pipe weights have been figured as neat tubes with 20 per cent added for rivet heads and lap joints, and experience has shown this to give very close to the actual weights for pipe of 60 inches diameter and from ¼ to 7/16 inch thickness of plate. A minimum thickness of 5/16 inch has been adopted for all steel pipe.

Reinforced Concrete Pipe.—The use of reinforced concrete pipe has been limited to heads of 70 feet or less, and a thickness of shell of 9 inches has been adopted, except that this has been reduced to 6 inches in the pumping proposition in cases where for long distances the pipe follows closely the hydraulic gradient.

Trenching, Pipe Supports, Etc.—Unit prices on pipe are on the basis of the pipe laid in place, but exclusive of trenching, backfilling, special supports, anchorage, drains, manholes, air valves and blowoffs. A unit price per foot has been assumed to cover all of these various items separate from the pipe.

Filtration Plant.—The filtration plant has been figured on the basis of that proposed for the Sacramento River project by Mr. Allen Hazen, the cost of operation being modified to allow for the more favorable quality of the raw water.

Distributing Reservoir.—It is considered essential to provide a small distributing reservoir at the most favorable point, which would be near Fruitvale, in order to equalize the flow and act in a measure as a surge chamber, breaking the long length of closed conduit. The somewhat high cost of this is due to the necessity of making it shallow in order to save head.

Carquinez Crossing.—It was first contemplated using four 36-inch cast iron pipes with flexible ball joints, the hydraulic gradient being figured on this assumption. A brief study develops the fact that a tunnel of 200 million gallons capacity could be built under these Straits, which are a mile in

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The delivery at only 20 feet elevation will, however, require the same or greater cost for pumps and pumping in San Francisco.—J. R. F.

The increased head of 200 feet on the 3.3 to 5 miles of harbor crossing adds to its cost, leakage and risk. Neither of these Feather River projects is attractive mechanically, apart from all question of cost.—J. R. F.

width with strong tidal currents, at a less initial cost than that necessary to lay the cast iron pipe with a capacity of only 60 million gallons daily, therefore the tunnel crossing was adopted.

Bay Crossing.—It is proposed to carry a riveted steel pipe on concrete pile trestle from Alameda Point to about the three mile station, where it is planned to erect a gate house on the edge of deep water; the gates here to be provided for cross connecting all pipes. From this point the water would be conveyed three and a half miles across under the harbor to San Francisco by means of a flexible ball joint cast iron pipe, laid in a dredged channel and backfilled. It is possible that in enlarging this project from 60 million gallon capacity to 200 million gallons, a tunnel could be driven under the Bay, instead of laying eight additional 36-inch pipes. This would afford an additional margin of safety against damage by earthquakes by providing separate types of crossing located some little distance apart.

Estimate of Cost.—The following estimate of cost of the gravity proposition has been prepared on a basis of an initial conduit capacity of 60 million gallons per day, except in the case of the tunnels, which, as before mentioned are planned for a capacity of 200 million gallons. In increasing the capacity from 60 million to 200 million gallons per day, it is assumed that this would be accomplished by the installation of two additional conduits similar to the first.

In the schedule the quantities directly under the particular heads apply to the initial development. The corresponding amounts for the 200 million gallon project are in general taken at three times that for the 60 million gallon project, except, of course, in those cases where the initial installation provides capacity for 200 million gallons per day.

Likewise in the cost of operation the quantities directly under the particular heads apply to the 60 million gallon project, the amounts set down under the 200 million gallon column are increased to what is considered a necessary amount for the additional attendance and supervision required.

FEATHER RIVER PROJECT.

SCHEDULE OF WORKS AND ESTIMATE OF COST.

(Gravity Filtration Proposition.)

		60 Mil. Gallons Per Day.	200 Mil. Gallons Per Day.	400 Mil. Gallons Per Day.
Diversion Dam—Head Works—				
Dam Crest 350 ft. Height 45 ft.				
12,000 cu. yds. concrete, at $8 ....$	96,000			
2,000 cu. yds. concrete, at $12	24,000			
5,000 cu. yds. excavation at $2..........	10,000			
Control Gates, Fish Ladder, Keepers' Quarters, etc.......	3,500	$ 165,000	$ 165,000	$ 165,000
Table Mountain Tunnel mi. 158.5-150				
10-Foot Bore. Concrete Lined.				
44,800 ft. at $60...$	2,692,800			
1,300 ft. shaft at $40.	52,000	2,744,800	2,744,800	5,489,600
Concrete Pipe—76-in. Inside Dia.				
9-inch thick reinforced for 70-ft. max. hd. mile 150-146.5 3½ mi.+5 per cent.				
19.404 ft. at $15....	291,060			
Trench, backfill, roads, drains, culverts—				
19,404 ft. at $4......	77,616	368,676	1,106,028	2,212,056
Steel Pipe (146.5-126.5)				
Riveted steel (55,000-lb. ultimate) 70 per cent eff. of joint. 76-inch diam.				
18,295 ft. 5/16-in. at $16.75	306,441			
12,751 ft. ⅜-in. at $20.15	256,932			
13,305 ft. 7/16-in. at $23.40	311,337			
66,528 ft. ½-in., at $26.80	1,782,950			
110,879 ft. trench, at $3.00	332,637	2,990,298	8,970,894	17,941,788
Concrete Pipe (126.5-126.1)—				
2,218 ft. 76-in. reinforced, at $15	33,270			
2,218 ft. trench, etc., at $4.00	8,872	42,142	126.426	252,852
Buttes Tunnel (126.1-122.3)—				
10 ft. bore, concrete lined, 20,064 ft. at $60	....	1,203,840	1,203,840	2,407,680
Conduit (122.3-99), 22.3 miles—				
1,663 ft. 76-in. concrete pipe, at $15.00	24,945			
40,471 ft. 76 x 5/16-in. steel pipe, at $16.00	677,889			
9,979 ft. 76 x ⅜-in. steel pipe, at $20.15	201,077			
16,077 ft. 76 x 7/16-in. steel pipe, at $23.40	376,202			
60,984 ft. 76 x ½-in. steel pipe, at $26.80	1,634,371			
81,654 ft. trench, at $3.00	244.962			
9 mi. trestle or concrete piers, at $50,000 per mi.	450,000			
Sacramento River crossing, extra work.	50.000	3,659.446	10,978.338	21,956,676
Conduit (Mile 99-29)—				
36 mi.+5% 76-in. concrete pipe, at $15.00	2,993,760			
34 mi.+5% 5/16 x 81-in. steel pipe, at $17.80	3,355,229			
Trenching, back-filling, roads, crossings and drains, 388,080 ft. at $4.00	1,552,320	7,901,309	23,703,927	47,407,854

		60 Mil. Gallons Per Day.	200 Mil. Gallons Per Day.	400 Mil. Gallons Per Day.
Carquinez Crossing (Mile 29-28)—				
5,280+1,000=6,280 ft. tunnel, steel and concrete lining, at $200	....	1,256,000	1,256,000	2,512,000
Conduit, mi. 28-24.8, 3.2 mi.+5%—				
17,740 ft. (76-in. concrete), at $15.00 . .	266,100			
17,740 ft. trench, at $3.00	53,220	319,320	957,960	1,915,920
Filtration Plant (as per Sacramento project)—				
Mechanical filters, 75 mil. gals., 27,000 sq. ft., including house laboratory, and all equipment, coagulator appliances and miscellaneous unclassified expenses, at $33.33	....	900,000	2,700,000	5,400,000
Coagulating basins and raw water and storage open, baffled and arranged for economical removal of sludge, 40 mil. gals., at $9,000	....	360,000	1,080,000	2,160,000
Pure water reservoir, covered, 10 mil. gals., at $13,000 . . .	....	130,000	390,000	780,000
Martinez and Oakland Tunnel—				
10-ft. bore, concrete lined:				
78,144 ft., at $60.00. .	$4,688,640			
1,500 ft. shaft, at $40.	60,000	4,748,640	4,748,640	9,497,280
Distributing Reservoir near Fruitvale—				
Flow line elev. 71.5 (covered), 120,000 mil. gals. capacity, at $10,000	....	1.200,000	3,600,000	7,200,000
Conduit (mi. 10-3.3)—				
37,144 ft. 5/16 x 81-in. steel pipe, at $17.80 per ft.	661,163			
26,056 ft. trench, repaving streets, at $5.00	130,280			
2 mi. piling, housing, at $55.00	110,000	901,443	2,704,329	5,408.658
Gate House (near mi. 3.3)—				
Cross-connecting all pipes	....	100,000	100,000	100,000
Bay Crossing (3.3-0)—				
4 lines 36-in. flexible joint cast iron pipe:				
658 lbs. per ft., at 2¼ cents	$14.80			
Lead:				
225 lbs. per 12 ft., at 6 cents	1.12			
Laying pipe, dredging channel and backfilling	55.00			
Per foot	$70.92			
18,295 ft., 4 lines, at $284	$5,195,780			
18,295 ft. reserve line, with lead and yarn, at $16.00	292,720	5,488,500	5,488,500	5,488,500
Tunnel (10-ft. bore)—				
18,295 ft., at $200....	....	....	3,659,000	3,659,000
Pipe to Pump Station—				
2,200 ft. 7/16 x 81-in. steel, at $25.00.....	55,000			
2,200 ft. trench, paving, at $6.00	13,200	68,200	204,600	409,200
Surge Pipe (carried to elev. 100)—				
1,000 ft. 48 x 5/16-in. steel, at $12.50	....	12,500	25,000	25,000
Telephone System, pipe walkers' cabins	....	50,000	50,000	50,000
		$34,610,114	$75,963,282	$142,439,064
15% for emergency and contingencies, 5% for extraordinary		6,722,023	15,152,656	28,487,813
Land and Rights of Way—				
152 miles, at $1,500. .	$228,000			
Site, filtration plant near Martinez, 160 acres, at $300.00 . ..	48,000			
Site, Fruitvale reservoir, 50 acres, at $60.00	300,000			
Diverting dam and reservoir, 640 acres, at $30.00	19,200			
	$595,200			
Legal, surveys, condemnation, 50% . ..	297,600	892,800	892,800	892,800
Total	....	$42,224,937	$92,008,738	$171,819,677

FEATHER RIVER PROJECT—COST OF OPERATION FOR FILTRATION SYSTEM DELIVERED BY GRAVITY TO 20 FEET ABOVE SEA TIDE IN SAN FRANCISCO.

	60 mil. gals. per day.		200 mil. gals. per day.	
Diversion dam, keeper and helper,	$ 2,100		$ 2,100	
Telephone lineman	1,500		1,500	
Conduit, 13 pipe walkers.......	14,040		28,080	
Gate house, 2 men...........	2,400		2,400	
Automobiles, wagons, etc.	10,000		15,000	
Occasional labor, divers, etc.....	25,000		50,000	
		$55,040		$99,080
Filter Plant Operation—				
Sulphate of alumina, ½ gr. per gal., 800 tons per annum, at $32.00	$25,600		$84,096	
Chloride of lime, 5 lbs. per mil. gals., 55 tons, at $40.00......	2,200		7,333	
Repairs and renewals, sand, lights, etc.	7,000		21,000	
One superintendent	3,000		4,000	
One assistant superintendent and chemist	2,400		2,400	
One assistant chemist	1,800		1,800	
Laborer, helper	1,200		1,200	
Three coagulent feed men......	3,600		7,200	
Seven filter men	8,400		16,800	

	60 mil. gals. per day.		200 mil. gals. per day.	
Two machinists	2,400		4,800	
One electrician	1,500		2,700	
Occasional labor	6,000		15,000	
		65,100		168,329
General Supervision and Office Expense	—	10,000	—	12,000
Total annual operating expense, exclusive of San Francisco Pumping Station	—	$130,140	—	$279,409
Capitalized Cost of Operation, Exclusive of City Pumping, at 4½%	—	$2,892,000	—	$6,209,000
Expense per million gallons	—	5.94	—	3.83

Pumping and Detention Project Storage at Hambre Without Filtration

Outline.—In this scheme it is proposed to utilize the same headworks outlined under the Gravity Proposition and practically the same conduit location. Starting from the diverting dam the first modification of any importance is the change in the hydraulic gradient from South Table Mountain to Martinez; permitting of a reduced conduit section and a lesser pressure on the pipe across the Sacramento Valley, thus reducing the weights and cost of same. Near Martinez the water would be delivered to a pumping station at a nominal head from which point it will be lifted to the reservoirs to be located in the Arroyo del Hambre, and which would be connected together by a tunnel. The flood line of these reservoirs would be at elevation 300, and the outlet tunnel at elevation 250, thus affording considerable emergency reserve as shown in Table I. From these reservoirs the water would enter a tunnel 13 miles in length, discharging into a small equalizing reservoir similar in design to that outlined for the gravity proposition, and thence delivered to San Francisco under a head of approximately 215 feet with correspondingly heavy pressure in the section 3.3 miles long beneath the harbor.

The conduit from the equalizing reservoir to San Francisco would be substantially the same as described for the gravity proposition modified to care for the additional pressure.

Martinez Pumping Station.—This station would contain four 20,000,000 gallon triple expansion verticle flywheel units with all auxiliaries, as outlined by Mr. Allen Hazen for the Antioch station for the Sacramento River project.

Arroyo del Hambre Reservoir.—From a study of the U. S. Geological Survey maps it appears that two reservoirs in close proximity to each other can be obtained by the construction of three dams assumed to be built of earth with approximate heights of 115 feet, 140 feet and 55 feet, and containing 901,200, 1,516,600 and 55,000 cubic yards respectively. These reservoirs would be interconnected by means of a tunnel of 200 million gallon daily capacity, and the water delivered to one and drawn from the other.

The watersheds of the two reservoirs combined as shown in Table I, amounting to 6,125 acres, it is assumed, will have to be bought outright and parked, to protect the stored water from contamination.

Oakland to Martinez Tunnel.—Owing to the higher elevation this tunnel will be approximately two miles shorter than the corresponding tunnel in the gravity proposition.

Estimate of Cost.—The same general remarks applied to the estimate of cost of the Gravity Proposition apply to the following estimate of cost of the Pumping Proposition.

For this alternative project an estimate was then made with same detail as that just previously described. These are given fully in the copies filed, but only the final results are presented here.

FEATHER RIVER PROJECT—COMPARATIVE COST OF GRAVITY AND PUMPING PROPOSITIONS.

SUMMARY.

	60,000,000 gallons development.		200,000,000 gallons development.	
	Gravity.	Pumping.	Gravity.	Pumping.
Construction cost	$41,332,137	$39,660,114	$91,115,938	$80,454,246
Land and right of way	892,800	843,300	892,800	843,300
Total plant cost	$42,224,937	$40,503,414	$92,008,738	$81,297,546
Capitalized cost of operation	2,892,000	4,485,350	6,209,000	11,638,000
Value of 195 feet difference of head in delivery to San Francisco	2,170,000	—	7,233,000	
	$47,286,937	$44,988,764	$95,450,738	$92,935,546
Difference in favor of pumping proposition	—	2,298,173	—	2,515,192

COST OF WATER DELIVERED IN SAN FRANCISCO.

Under 215 feet head.

		Per mil. gals.
60,000,000 Gallon Development—		
Annual charges, interest and depreciation on $40,503,414, at 6 per cent	$2,430,205	110.97
Operating expense	201,841	9.21
Total	$2,830,046	120.18
200,000,000 Gallon Development—		
Annual charges, interest and depreciation on $81,297,546, at 6 per cent	$4,877,853	66.82
Operating expense	523,717	7.17
Total	$5,401,570	73.99

In the estimated cost of the plan no account has been taken of the cost of making what would appear to be the necessary arrangement with the Great Western Power Co. in regard to the City gaining a positive control of the amount of water to be turned down from their storage as the same is required for use below.

Conclusions

In conclusion it appears that in event of a necessity for utilizing the Feather River as a source of supply for the Metropolitan district about San Francisco, that up to the extent of 200,000,000 gallons daily it would be cheaper to adopt a line of development as outlined for the Pumping Proposition. At such time when the demand exceeds 200,000,000 gallons per day it will be necessary to install a filtration plant to take care of the additional demand.

The cost of an initial development of 60,000,000 gallons per day would amount to approximately $45,000,000 plus probably $1,000,000 for water rights; the cost of the 200,000,000 gallon project would be nearly $93,000,000 with another $1,000,000 added for water rights.

It is extremely doubtful if the advantage of the Feather River in regard to the quality of the water is sufficient to offset the additional $22,000,000 necessary to develop this project in preference to the Sacramento River Filtration Project.

Note: The three sheets of drawings accompanying this report are not reproduced here, but copies are included with each of the three copies of this report placed on file with the Advisory Board of Army Engineers.

Sheet No. 1 shows lines and areas of equal rainfall.

Sheet No. 2 shows provisional location of conduit line, Big Bend to San Francisco.

Sheet No. 3 shows profile of ground along aqueduct, also hydraulic gradients for gravity and pumping projects.

Appendix No. 16

YUBA RIVER AS A SOURCE OF WATER FOR SAN FRANCISCO

By C. E. GRUNSKY, Consulting Engineer.

July 31, 1912.

Yuba River received consideration as a source of water for San Francisco in 1901. At that time the writer, then City Engineer, directed a careful examination particularly with a view of determining the merits of a proposition then made by the Marysville and Nevada Power and Water Company to supply water to San Francisco.

Reservoirs and canal routes so far as necessary to determine feasibility and to serve as a basis for a cost estimate were made and the results of the work was set forth in a progress report filed on August 12, 1901, with the Board of Public Works (see Mun. Reports 100-01, pages 384 and 409, etc.).

The cost of bringing 60,000,000 gallons of water per day from the North Fork of the Yuba River to San Francisco was then estimated at $38,608,300.00. The project, as at that time outlined, included filtration of the water and it was assumed that the Bay of San Francisco would have to be crossed by tunnel. No estimate was made for large amounts of water such as 200,000,000 gallons per day or 400,000,000.

This river falls so closely into the same category as the Feather River in so far as character of watershed and sufficiency of supply is concerned, and also in the matter of a conduit route to San Francisco that only a few words need be added to what has been said in earlier reports.

The flow of the river is indicated by results of gagings made by the U. S. Geological Survey and published in Water Supply papers. These results by months are shown in the following table:

The water shed of the Yuba River and particularly of the North Fork of the Yuba is already well occupied by power companies and all conveniently available storage sites are in use or their early use is contemplated. Such use is an advantage to a diversion of water for municipal purposes, because it will aid materially in equalizing the otherwise irregular stream flow. The naturally large water output from the watershed of the Yuba River, which has an area of about 1220 square miles, at the junction of the North and South Forks, will be increased by all such storage at the times when the river is at low stages. It may confidently be assumed that this river will be able to supply not only the water that may ultimately be required by a comparatively small valley area dependent upon it for irrigation water, but also such water as should be available for San Francisco and for a Metropolitan Water District, which will ultimately be in need of water in large amount from some remote source, such as this river.

However, not all of the water that may be ultimately required for use in and near San Francisco, will be the natural stream flow. Some of it will come from storage whether the same is finally owned or controlled as a part of the water supply project, or whether it is simply diverted because no one else has a superior right to the waste flow from power stations.

It may be well conjectured that if the City goes about the securing of rights on the Yuba River that it will find itself in more or less conflict with such projects as that known as the Hotle project for the irrigation of lands between the Yuba and Feather Rivers, and with those who control the waters

TABLE I—YUBA RIVER DISCHARGE AT SMARTSVILLE.

From Records of U. S. Geological Survey. Drainage Area=1,230 Square Miles.

In Acre Feet.

Month.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.
January		118,302	301,500	465,000	307,000	208,000	1,410,000	278,000	480,000
February		857,805	278,100	276,000	783,000	128,000	541,000	244,000	381,000
March		946,848	437,000	738,000	1,060,000	221,000	328,000	502,000	509,000
April		633,005	401,700	522,000	780,000	286,000	437,000	470,000	626,000
May		649,371	373,300	664,000	538,000	320,000	520,000	288,000	508,000
June	173,217	276,694	184,500	595,000	402,000	189,000	388,000	76,200	568,000
July	55,277	71,080	48,080	206,000	188,000	43,300	83,600	32,300	158,500
August	31,728	35,663	28,960	45,700	45,300	21,500	37,200	20,200	37,400
September	28,502	37,904	25,530	30,900	30,000	19,600	25,600	22,500	27,000
October	33,818	114,060	27,850	24,800	31,800	32,000	33,400	23,900	29,200
November	291,154	70,215	28,200	45,000	28,100	284,000	298,000	38,900	36,700
December	123,529	140,192	34,800	254,000	97,800	47,000	403,000	86,100	30,600

liberated from reservoirs at points in the watershed above the proposed point of diversion. Some of the stored water, if not subject to ownership or control by San Francisco, will be used and liberated by the power companies in the basins of the other streams and will in such event fail to reach the proposed point of diversion.

Such matters as these would require careful consideration if the Yuba River should really come into serious consideration as a source of supply. They have not been investigated because it is clearly evident that even on the admission of an abundance of water this river, as a source of supply, has too many disadvantages in comparison with other sources to entitle it to more than passing notice.

A YUBA RIVER PROJECT

It is believed that the best point for the diversion of water from Yuba River for a San Francisco project would be just below the junction of the North and South Forks. This point commands the full stream flow and is high enough, about 500 feet above sea level, to permit of a gravity delivery of the water to San Francisco.

If a project were carried out it would be substantially the same as the Feather River project. There would be a low masonry diverting dam across the river. Tunnels and covered canal would bring the water westerly out upon the plains of the Sacramento Valley and a steel conduit (a 60,000,000 gallon capacity being assumed) would at the Marysville Buttes fall upon the line and be under nearly the same hydraulic pressure as the line described for a Feather River project.

The cost estimate submitted for the Feather River project may therefore stand almost without modification for the Yuba project.

The length of conduit for the Yuba project, connecting with the line as projected for the Feather River Aqueduct at a point just southwest of the Marysville Buttes is 157 miles, just one and one-half miles shorter than that of the Feather River Route. Making allowance for the difference in length of the tunnel and conduit involved, the cost of a Yuba River Project may be estimated as follows:

Yuba River Project.—Estimated cost of delivery to San Francisco, 60,000,000 gallons per day, under a head of 20 feet above sea level, $43,900,000, which includes cost of works and capitalized cost of operation.

The Yuba River project may have some advantages over a filtration project, with a supply from the lower Sacramento River at Rio Vista, by reason of better quality of the water. Population on the watershed of the Yuba River is not dense and the water, like all the waters of the Sierra Nevada rivers, is soft and well adapted for domestic and industrial uses. But if taken from the main stream, as proposed, it cannot be called acceptable without filtration.

The question therefore arises whether some advantage of quality and the advantage of a gravity flow to the Bay region would offset the disadvantage of the lower Sacramento River from which water must be raised by pumping and from which a water somewhat inferior in quality is to be expected. The same remarks in this connection which were made in the discussion of the Feather River project apply also in the case of a Yuba River project.

The conduit location, as herein suggested, is shown on a small location map, and the watershed on a map based on the U. S. Geological Survey sheets. The profile of the conduit, as in the case of the Feather River project, is based on map studies, with no detail surveys or examinations of the conduit route.

C. E. GRUNSKY, Consulting Engineer.

Appendix No. 17

ABSTRACT OF REPORT ON THE MODESTO AND TURLOCK IRRIGATION DISTRICTS AND THEIR RELATION TO A WATER SUPPLY FOR SAN FRANCISCO AND ITS NEIGHBORING CITIES FROM THE UPPER TUOLUMNE RIVER

By J. H. Dockweiler, C. E.

(This report, of which this is an abstract, was placed on file in triplicate with the Advisory Board of Army Engineers on July 15, 1912.)

Scope of Report

The report on the Modesto and Turlock irrigation districts treats of the uses of water from the Tuolumne River, California, the water needs of the said districts and the quantity of water remaining available for storage and diversion to the cities surrounding San Francisco Bay.

The relation of water supply to the cities around San Francisco Bay from the Tuolumne River to the needs of water for irrigation in the Modesto and Turlock irrigation districts is discussed.

San Francisco's Requirements and Satisfaction of Irrigation Priorities

In the first 18 pages Mr. John R. Freeman, Consulting Engineer, shows that the requirements of the cities around the Bay of San Francisco will, in all probability, be at least 400 million gallons of additional water daily; that this quantity of water can be prudently met from the Upper Tuolumne River by means of 3 dams and reservoirs, to be constructed at the outlet of the Hetch Hetchy Valley, Lake Eleanor and Cherry Valley, and from the report of Mr. Dockweiler's investigation he finds that this quantity of water can be diverted without impairing in the slightest degree the fertility or agricultural development of the Modesto and Turlock districts—and without encroachment on their rights, and states that it is the purpose of the City to befriend these districts, and that the City's improvement will be beneficial to them.

He also discusses the water claims of the districts; the area irrigable from the Tuolumne River fixed by natural conditions; the fact of present excessive use of water or over-irrigation; limits of beneficial use of water; that the City of San Francisco can obtain 500 million gallons of water daily in the future, without interfering with the irrigation districts; and, further, the yield of water from the catchment areas in the Tuolumne River watershed, proposed for San Francisco's use.

The Turlock-Modesto Needs as Confirmed by Colorado Experience

Mr. Freeman's report enclosed the report of Mr. George T. Prince, Consulting Engineer, who visited the Modesto and Turlock districts at Mr. Freeman's request, and whose report treats of the duty of water in East Colorado; depth required for various crops; tendency toward using less water, with better knowledge regarding correct methods of irrigation; dependency of depth of water upon rainfall; the question of return waters as compared with conditions in Colorado; comparison of climate of these districts with that of Colorado; the rise of the water table, due to excessive irrigation; sub-irrigation or cultivation of the soil without surface irrigation taken place in these districts. Comparisons of depth of water used with depth used in Colorado are also shown. Examination of the local conditions show that a duty of 1½ acre-feet of water per year should be sufficient as an average throughout the Modesto and Turlock irrigation districts. Furthermore than an allowance of 2½ acre-feet per year on the soil is over ample and probably unnecessary; an allowance of 2 acre-feet should be sufficient.

Mr. Dockweiler's Investigation In the Field

The report of J. H. Dockweiler, Consulting Engineer, on the conditions in the Modesto and Turlock irrigation districts consists of a report dated January 29, 1912, with a supplemental report dated June 27, 1912. The main report comprises 218 pages with an appendix of 62 pages. Numerous photographs, maps, diagrams and tables illustrate the text. The supplemental report comprises 25 pages. The report of January 29, 1912, is the result of a field investigation undertaken at the request of Mr. John R. Freeman, Consulting Engineer, between July 26 and October 16, 1911, and during the period of 4 days from December 30, 1911, to January 2, 1912, and office studies and compilations of the data obtained. An outline of the work is given on pages 4 to 10.

The Extent of the Irrigable Land

The Modesto and Turlock irrigation districts are situated in the San Joaquin Valley, State of California, about 100 miles east of San Francisco, and have a combined area of 257,353 acres. The districts are furnished with water for irrigation purposes from the Tuolumne River, through works constructed by each district, which works are supplied with water by means of the La Grange Dam, built on the river at the joint expense of the two districts. The description of the Modesto and Turlock irrigation districts is set forth at pages 11 to 13. The La Grange dam and reservoir are described. Photographs of the dam and reservoir appear; also of the highest recorded flood of the Tuolumne River over the La Grange Dam, of January 31, 1911.

Local Storage of Water Diverted

Both districts proposed to store water available to them under their priorities on the days when it may not be needed for application to the ground. The storage reservoirs, built and proposed, of the districts are described—the Modesto district having constructed on its side of the river, between the district and the La Grange Dam, a reservoir holding 30,000 acre-feet. Both districts have reservoir sites and the total storage capacities of the reservoirs would be 168,000 acre-feet. The combined districts have a grand total of 305 miles of canals and laterals.

The annual rainfall for the districts is 10 inches; normal annual temperature is 63.9.

Character of Soil

Soils and soil conditions have been investigated by the United States Department of Agriculture and reference is made to their publication for a statement of the facts. A map of the alkali areas of the districts—and giving the percentage of alkali—is shown. Practically but 1,000 acres contain alkali to a harmful degree. Analyses of the seepage and drainage waters flowing from the district show them to be suitable for the purpose of irrigation.

The Wastefulness of the Present Application of Water

About 40 per cent of the water at present used on the land is waste or excessive use.

Interviews of residents relative to excessive use of water on the land are set forth. The amount of water wasted during the year 1911 through excessive use in these districts is sufficient for a year's water supply of a city of 1,160,000 inhabitants, allowing each person 150 gallons per day. Seepage water investigations were undertaken along the rivers in the districts. Results show that the seepage along the banks of the rivers is greatest during the irrigation season and decreases when irrigation gradually ceases. Dry Creek, in Modesto district, which before irrigation was dry, is now a running stream throughout the entire year. It discharged 16 second-feet in September, 1911.

The depth to water was measured in 440 wells—as near as possible a well was measured for each section of 640 acres within the area of the two districts. This and other data obtained regarding wells is tabulated and covered by 62 pages.

As the result of excessive use of water, a total of 137,000 acres in both districts, or 53 per cent of the combined area of both districts, had water at ten feet and less below the surface. In the Modesto district 20 wells measured by the United States Government in 1904 were measured in 1911. They showed an average rise of 12.3 feet, ranging from 3 to 26 feet, during the 7 year interval.

Twenty-five of the wells in the Turlock district measured in 1911 had been measured at a date previous. The water had risen in every one of the wells—the longer the period the greater the rise, ranging as high as 23 feet.

Similarly in all of fifty-two wells in the Modesto district the water had risen.

Excessive Irrigation is Injuring Large Areas, Creating Pools and Swamps

Quoting a publication of the United States Department of Agriculture, the ground water began to rise with the first irrigation. Ground water rise, evidenced by flooded cellars, led to the formation of lakes.

Numerous measurements were made of wells in both districts which showed that there was a gradual drop from the time that the peak of the irrigation season had passed. The water being nearest to the surface at the height of the irrigating season and gradually dropping as irrigation became lessened. Pages 119 to 131 contain the tabulations, diagrams and maps explanatory of the text. The injurious effects of a fluctuating water table are dwelt upon. (Pages 132 and 133.) The damage caused by the rise of ground water is confirmed by interviews with owners and tenants in both districts. As a result of the excessive use of water, twelve lakes have been formed in the Modesto and Turlock districts. The total area of the lakes is about 182 acres, in addition to which margining them there are large areas of practically swampy lands. During the height of the irrigation season water collects in depressions in both districts, forming lakes which disappear at the end of the season. These lakes are not included in the foregoing number. (See page 137 of typewritten report *et seq.* for photographs of lakes.)

Drainage Work in Progress to Remedy Damage by Over Irrigation

At page 145 *et seq.* will be found descriptions of the drainage ditches constructed in both districts. Within a very short time after irrigation began, the ground water rose to injurious heights over large areas.

In 1907 pumping experiments were conducted in each district with a view to draining the soil. Owing to the nature of these experiments and the poor showing made by the pumps, the open ditch method of drains was agreed upon. By the year 1909 about 22 miles of drain ditches equally divided between the two districts had been built. After completion, lack of maintenance caused these ditches to choke up with tules and other obstructions, caving banks, etc. (See photographs, page 146 *et seq.*) Despite the drainage ditches the ground water stands at injurious heights over large areas in both districts. In the Turlock district it is between 5 and 6 feet below the surface in land through which the main drain passes. The Turlock district looks to solve the drainage problem by means of electrically driven pumps, placed in sumps below the level of the land. The water is to be pumped into the irrigation canals. The Turlock district has bonded itself for the sum of $163,000 for the aforesaid pump installation, as per the statement of the chief engineer of said district.

In the Modesto district no definite plans have been decided upon for drainage. On pages 157 *et seq.* the advantages of ditches over pumping plants are discussed. Page 158 shows the location of the drainage ditches of both districts.

It is estimated when 2¼ feet in depth of water are applied annually upon 206,000 acres in the districts, that 51,620 acre-feet of water will have to be pumped annually by the districts to keep the ground water 10 feet below the surface. This water can be used again for irrigation. (Pages 161 and 162.)

At pages 166 *et seq.* will be found the number of acres irrigated in each of the districts.

The Present Application of Irrigation Water

During the year 1905 the Modesto district irrigated nearly 7,900 acres, or 10 per cent of the area of the district. The water diverted by the Modesto canal at La Grange during this year, if evenly distributed over this area, would have covered each acre irrigated to a depth of 10½ feet. (Page 166.)

In this district during the year 1911 about 35,000 acres, or 43 per cent, of the district's area was irrigated. ***The amount of water diverted by the Modesto canal from the Tuolumne River at La Grange during the year would have covered each acre irrigated to a depth of 5 feet if evenly distributed.***

Of the area irrigated in the Modesto district in 1911, 20,600 acres had the ground water from 5 to 10 feet from the surface in August.

In the Turlock district the area irrigated during 1911 was about 71,000 acres, or 40 per cent of the district. The water diverted at La Grange dam during the year, if evenly distributed, would have covered each acre irrigated to a depth of 4.24 feet.

Of the area irrigated in 1911 in Turlock district, 40,100 acres had the ground water from 5 to 10 feet below the surface in August.

During the eight year period, 1904-1911, the water diverted by the Modesto canal, *if distributed evenly over the area irrigated each year in the Modesto district, would have covered each acre from 12 feet in depth in 1904 to 5 feet in 1911.*

During the 11 year period, 1901-1911, for the Turlock district the water diverted by the Turlock canal, similarly applied, would have covered each acre irrigated in the district 16 feet in 1902 and 4.24 feet in 1911. (Page 174.)

Conclusion as to Reasonable Use of Irrigation Water

Each acre irrigated is to receive 2½ feet in depth of water annually; from the Tuolumne River 2¼ feet and from recovery water ¼ foot. The amount of water that both districts can beneficially use with the maximum area—206,000 acres—irrigated from the Tuolumne River, is 533,050 acre-feet—equals 737 cubic feet per second flowing for one year. With storage drawn from present and proposed reservoirs below La Grange dam, 8 per cent is to be added to above quantity. (See page 176.)

The Crops Raised Here by Irrigation

On page 177 is given a tabulation showing the various crops raised each year during the last three years, on land irrigated in the Modesto district.

On page 178 is given similar data for the last six years in the Turlock district.

Pages 179-181 treat of crops which may ultimately be raised. Also profits of feeding value of alfalfa.

On pages 182-194 the amount of water required by various crops is set out. (Duty of water.)

On page 190 it is shown why water should not be used imprudently.

Pages 191-193 give the effect of regulating the amount of water used upon land.

The amount of water appropriated by the irrigation districts from the Tuolumne River. (Page 196.)

Record of River Discharge and Water Diverted

Table on page 198 gives monthly discharge of the Tuolumne River for three periods between 1879 and 1911. The average annual flow at La Grange dam for the 16-year period 1896-1911, equals about 2,200,000 acre-feet, maximum in year 1907, 3,710,000, minimum, 850,000 in 1898. The minimum year was 39 per cent, maximum year 169 per cent of the average annual flow.

At page 201 the dates when water was first turned in and last turned out in Modesto and Turlock canals for each year and on page 202 dates for last runs of laterals are given for one year.

The monthly distribution of water as used in the combined quantities of discharge of both the Modesto and Turlock canals during the year 1911, was used to determine the monthly percentages for the distribution of the maximum quantity of water required by the districts, with 206,000 acres irrigated each year.

The Need for Local Storage

Storage will be required by the districts. An application has been made of the monthly quantities of water required by the districts when irrigating 206,000 acres annually, to the flow of the Tuolumne River for the period 1898-1911, with the result that two years, 1906 and 1907, would have required no storage water, all the others would have drawn from storage ranging from 3017 acre-feet in 1911 to 159,924 in 1898. (Pages 204-208.)

The storage capacity of the districts' proposed reservoirs is 168,000 acre-feet.

Finances of These Irrigation Districts

The total combined construction cost of Modesto and Turlock districts is $3,568,921; Modesto $1,781,677, Turlock $1,787,244.

The annual assessment on each acre in the district for the year 1910 was, Turlock $1.76, Modesto $1.94. (Pages 212-215.)

Modesto-Turlock Supplemental Report, Appendix B, Pages A to X

The object of the report was to ascertain, first, the probable quantity of water flowing in the Tuolumne River annually past the La Grange dam, after the Modesto and Turlock irrigation districts' maximum yearly requirements (533,050 acre-feet) for beneficial use have been met, together with the proposed diversion of 400 million gallons daily to San Francisco from said river. Second, whether any lands contiguous to the Tuolumne River other than those of the Modesto and Turlock irrigation districts are susceptible to irrigation.

The Water Remaining After Satisfying All Irrigation Needs

The results of the study are, first, that the total quantity of water wasted yearly over La Grange dam, after satisfying Modesto and Turlock irrigation districts' and San Francisco's requirements, based upon the application of said requirements to the discharge of the Tuolumne River for the past sixteen years, 1896-1911, varies from a minimum of 91,385 acre-feet in 1898 to a maximum of 2,733,392 acre-feet in 1907.

No Other Important Areas Remain to be Irrigated from this Source

Second, that there is a region lying east of the Modesto and Turlock irrigation districts, through which the Tuolumne River flows, portions of which can be irrigated with water diverted from the Tuolumne River. The precise area of the same has not been determined, but plainly it is so small compared with the area of said irrigation districts that it can not affect the amount of water available to San Francisco in any important degree.

The following table is typical of the computations undertaken in this supplemental report covering all the years since gaugings began at La Grange and which illustrates that after supplying both the irrigation districts with their full priorities and more water than they can beneficially use and after supplying San Francisco district with 400 million gallons daily water will still run to waste or be available for other purposes.

MONTHLY VOLUME OF WATER AVAILABLE TO SAN FRANCISCO AFTER SUPPLYING IRRIGATION PRIORITIES OF THE TURLOCK AND MODESTO IRRIGATION DISTRICTS, FOR YEARS 1910 AND 1911. BASED UPON THE U. S. GEOLOGICAL SURVEY'S RIVER GAGINGS AT LA GRANGE AND UPON IRRIGATING 206,000 ACRES EACH YEAR. QUANTITIES IN ACRE FEET. Computed by J. H. Dockweiler, C. E.

MONTH.	Discharge of Tuolumne River at La Grange. U. S. Geological Survey records. Total watershed area, 1,548 square miles.	*Modesto-Turlock Irrigation District.*						*Tuolumne River Watershed.*			*San Francisco's Watershed Areas.*	
		2,350 second feet, appropriation of Turlock and Modesto Irrigation Districts.	Irrigation requirement for application to crops, plus 15 per cent waste on 206,000 acres. (Dockweiler.)	Remainder of appropriation available for storage, comprising remainder of 2,350 second feet, or flow of river when same is less than 2,350 second feet.	Quantity devoted to storage, by districts. Quantity taken from storage.	Reservoir capacity of districts, 168,000 acre feet. Total into storage evaporation not added. Mass curve.	Total quantity taken by irrigation districts from Tuolumne River.	Dicharge from San Francisco's three watersheds. Hetch Hetchy, Eleanor and Cherry. *Area, 658 square miles.*		Discharge from remainder of Tuolumne River watershed above La Grange Dam. Area, 890 square miles.	Quantity which must flow from San Francisco's watersheds to furnish irrigation districts' requirements. (Dockweiler.)	Quantity available to San Francisco from its three watersheds after irrigation districts have taken quantity which they can beneficially use.
								Per cent of total Tuolumne watershed discharge at La Grange.	Quantity.			
1910.	Col. 1.	Col. 2.	Col. 3.	Col. 4. 2-3 or 1-3.	Col. 5.	Col. 6.	Col. 7. 3+5 or 1.	Col. 8.	Col. 9. 1 x 8.	Col. 10. 1-9.	Col. 11. 7-10.	Col. 12. 9-11.
						*168000						
Jan.	194000	144500	0	144500	0	168000	0	37	71780	122220	0	71780
Feb.	105640	130510	3635	102005	0	168000	3635	40	42256	63384	0	42256
Mar.	238100	144500	44670	99830	0	168000	44670	36	85716	152384	0	85716
Apr.	416000	139830	86727	53103	0	168000	86727	46	191360	224640	0	191360
May	461400	144500	106253	38247	0	168000	106253	62	286068	175332	0	286068
June	198100	139830	104616	35214	0	168000	104616	71	140651	57449	47167	93484
July	48700	144500	106072	0	-57372	110628	48700	78	37986	10714	37986	0
Aug.	8300	144500	61653	0	-53353	57275	8300	67	5561	2739	5561	0
Sept.	13450	139830	13198	252	252	57527	13450	70	9415	4035	9415	0
Oct.	12928	144500	5646	7282	7282	64809	12928	71	9179	3749	9179	0
Nov.	16800	139830	581	16219	16219	81028	16800	67	11256	5544	11256	0
Dec.	36100	144500	0	36100	36100	117128	36100	50	18050	18050	18050	0
TOTAL ..	1749518	1701330	533051	532752			482179		909278	840240	138614	770664 250 bil. gals.
*Carried forward from 1909.												
1911						*117128						
Jan.	369296	144500	0	144500	50782	168000	50872	30	**110798	258498	0	110798
Feb.	217475	130510	3635	126875	0	168000	3635	32	68249	149226	0	68249
Mar.	445465	144500	44670	99830	0	168000	44670	22	99694	345771	0	99694
Apr.	435111	139830	86727	53103	0	168000	86727	44	189885	245226	0	189885
May	511940	144500	106253	38247	0	168000	106253	63	322679	189261	0	322679
June	813998	139830	104616	35214	0	168000	104616	85	692554	121444	0	692554
July	447564	144500	106072	38428	0	168000	106072	89	398757	48807	57465	341292
Aug.	59773	144500	61653	0	-1880	166120	59773	77	46105	13668	46105	0
Sept.	12061	139830	13198	0	-1137	164983	12061	75	9064	2997	9064	0
Oct.	5796	144500	5646	150	150	165133	5796	97	5387	409	5387	0
Nov.	4745	139830	581	4164	2867	168000	4745	111	5665	-920	4745	920
Dec.	11403	144500	0	11403	0	168000	0	32	3692	7711	0	3692
TOTAL ..	3334627	1701330	533051	551914			583923		1952529	1382098	122766	1829763 595 bil. gals.

*Carried forward from 1910.

**Actual gauges from San Francisco's watersheds by City Engineer of San Francisco during year 1911.

YEARLY VOLUME OF WATER AVAILABLE TO SAN FRANCISCO AFTER SUPPLYING IRRIGATION PRIORITIES OF THE TURLOCK AND MODESTO DISTRICTS. BASED UPON U. S. GEOL. SURVEY'S RIVER GAGINGS AT LA GRANGE AND UPON IRRIGATING 206,000 ACRES EACH YEAR. QUANTITIES IN ACRE FEET.

Computed by J. H. Dockweiler, C. E.

YEAR.	Discharge of Tuolumne River at La Grange. U. S. Geological Survey records. Total watershed area, 1,548 square miles.	*Modesto-Turlock Irrigation District.*							*Tuolumne River Watershed*		*San Francisco's Watershed Areas.*		
		2,350 second feet appropriation of Turlock and Modesto Irrigation Districts if continuous for whole year.	Irrigation requirement for application to crops 2.25 feet deep on 206,000 acres plus 15% waste (Dockweiler).	Remainder of appropriation available for storage, comprising remainder of 2,350 second feet, or flow of river when same is less than 2,350 second feet.	Quantity possibly diverted to storage, by districts.	Quantity possibly taken from storage, by districts.	Reservoir capacity of districts, 168,000 acre feet. Total into storage. Evaporation not added. Mass curve.	Total quantity possibly taken by irrigation districts from Tuolumne River.	Discharge from San Francisco's three watersheds, Hetch Hetchy, Eleanor and Cherry. Area, 658 square miles.	Discharge from remainder of Tuolumne River watershed above La Grange Dam. Area, 890 square miles.	Quantity which must flow from San Francisco's watersheds to furnish irrigation districts' requirements. (Dockweiler.)	Quantity available to San Francisco from its three watersheds after irrigation districts have taken quantity which they can beneficially use. Acre feet.	Billion gals.
	Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 5½.	Col. 6.	Col. 7.	Col. 9.	Col. 10.	Col. 11.	Col. 12.	
1896.....	1698100	1701330	533051	618129	199825	31825	168000	701051	993792	704308	162028	831764	*255
1897.....	2422827	1701330	533051	577999	55161	55161	168000	533051	1330280	1092547	136947	1193333	366
1898.....	854496	1701330	533051	242775	17481	159924	25557	390608	467660	386836	95157	372503	114
1899.....	1682006	1701330	533051	603391	245192	102749	168000	675494	950004	732002	139897	810107	247
1900.....	1612330	1701330	533051	715440	122520	122520	168000	533051	929754	682576	120906	808848	248
1901.....	2586990	1701330	533051	659431	10232	10232	168000	533051	1452844	1134146	105196	1347648	414
1902.....	1571231	1701330	533051	409323	65985	65985	168000	533051	851131	720100	118713	732418	224
1903.....	1968955	1701330	533051	537006	72226	72226	168000	533051	1113541	855414	127983	985558	306
1904.....	2862378	1701330	533051	658803	14369	14369	168000	533051	1664202	1198176	113504	1550698	475
1905.....	1440568	1701330	533051	386621	11052	83444	95608	460659	809876	630692	86490	723386	222
1906.....	3629200	1701330	533051	727859	72392	0	168000	605443	2191528	1437672	23360	2168168	666
1907.....	3714400	1701330	533051	693519	0	0	168000	533051	2088561	1625839	22664	2065897	633
1908.....	1045500	1701330	533051	380932	42573	87323	123250	488301	577773	467727	161300	416473	127
1909.....	2992880	1701330	533051	828100	80521	35771	168000	577801	1669421	1323459	96123	1573298	483
1910.....	1749518	1701330	533051	532752	59853	110725	117128	482179	909278	840240	138614	770664	236
1911.....	3334627	1701330	533051	551914	53889	3017	168000	583923	1952529	1382098	122766	1829763	254
TOTALS	35166006	27221280	8528816	9123994	1123271	955271		8696816	19952174	15213832	1771648	18180526	

*In considering the last column, note that 500 million gallons per day for 365 days, or one year, amounts to only 182 billion gallons, far more than which is available in all of the above years, except 1898 and 1908, and in those years the storage could have supplied it from the surplus of the previous year.

YEARLY VOLUME OF WATER THAT WOULD HAVE WASTED AFTER SUPPLYING SAN FRANCISCO WITH 400 MILLION GALLONS DAILY AND SUPPLYING THE TURLOCK AND MODESTO DISTRICTS THEIR FULL PRIORITIES OF 2350 SECOND FEET FOR 206,000 ACRES. BASED UPON THE U. S. GEOLOGICAL SURVEYS, RIVER GAGINGS AT LA GRANGE FOR 16 YEARS AND CITY'S GAGINGS AT DAMSITES FOR PARTS OF THREE YEARS. QUANTITIES IN ACRE FEET.

Computed by J. H. Dockweiler, C. E.

CALENDAR YEAR.	*Tuolumne River Watershed.*			*Modesto-Turlock Irrigation Districts.*				Quantity available to San Francisco from its three watersheds after irrigation districts have taken quantity which they can beneficially use.	Aggregate quantity diverted to San Francisco, drawing 400 million gallons daily =447,957 acre feet yearly.	Quantity wasted by San Francisco from its watersheds, based upon its reservoirs being empty previous year.	Quantity wasted at La Grange from discharge of 890 sq. m. of Tuolumne watershed below San Francisco's damsites after irrigation districts take all they can use beneficially.	Total quantity wasted over La Grange Dam, or quantity available for later appropriation after satisfying both irrigation districts and San Francisco.	Percentage of total discharge of Tuolumne River wasted.
	Discharge from San Francisco's three watersheds—Hetch Hetchy, Eleanor and Cherry. Area, 658 square miles.	Discharge from remainder of watershed above La Grange. Area, 890 square miles.	Total natural discharge from watershed above La Grange. U. S. Geological Survey records. Area, 1,548 square miles above La Grange.	Quantity that must be released from San Francisco's watersheds. Portion taken by irrigation districts to satisfy their priorities of 2,350 second feet, when useful.	Quantity from remainder of Tuolumne watershed. Portion taken by irrigation districts to satisfy their priorities, when useful.	Total maximum quantity that can be taken from entire Tuolumne watershed by irrigation districts at La Grange for beneficial use.	Reservoir capacity of irrigation districts' full proposed development, 168,000 acre feet. Quantity contained in reservoirs at end of year.						
	Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5. 6—4.	Col. 6.	Col. 7.	Col. 8. 1—4.	Col. 9.	Col. 10. 8—9.	Col. 11. 2—5.	Col. 12. 10 x 11.	Col. 13. 12+3.
1896.....	993792	704308	1698100	162028	539023	701051	168000	831764	447957	383807	165285	549092	32
1897.....	1330028	1092547	2422827	136948	396103	533051	168000	1193332	447957	745375	696444	1441819	60
1898.....	467660	386836	854496	95137	295451	390608	25557	372503	447957	0	91385	91385	11
1899.....	950004	732002	1682006	139897	535597	675494	168000	810107	447957	362150	196405	558555	33
1900.....	929754	682576	1612330	120906	412145	533051	168000	808848	447957	360891	270431	631322	39
1901.....	1425844	1134146	258990	105196	427855	533051	168000	1347648	447957	899691	706291	1605982	62
1902.....	851131	720100	1571231	118713	414338	533051	168000	732418	447957	284461	305762	590223	38
1903.....	1113541	855414	1968955	127983	405068	533051	168000	985558	447957	537601	450346	987947	50
1904.....	1664202	1198176	2862378	113504	419547	533051	168000	1550698	447957	1102741	778629	1881370	66
1905.....	809876	630692	1440568	86490	374169	460659	95608	723386	447957	275429	256523	531952	37
1906.....	2191528	1437672	3629200	23360	582083	605443	168000	2168168	447957	1720211	855589	2575800	71
1907.....	2088561	1625839	3714400	22664	510387	533051	168000	2065897	447957	1617940	1115452	2733392	74
1908.....	577773	467727	1045500	161300	327000	488300	123250	416473	447957	0	140727	140727	14
1909.....	1669421	1323459	2992880	96123	481678	577801	168000	1573298	447957	1125341	841781	1967122	66
1910.....	909278	840240	1749518	138614	343565	482179	117128	770664	447957	322707	496675	819382	47
1911.....	1952529	1382098	3334627	122766	461157	583923	168000	1829763	447957	1381806	920941	2302747	69
TOTAL..	19952174	15213832	35166006	1771649	6925166	8696812		18180525	7167312	11120151	8288666	19408817	

Appendix No. 18

THE MOKELUMNE RIVER AS A SOURCE OF WATER SUPPLY FOR SAN FRANCISCO

Summary Report by C. E. GRUNSKY, Consulting Engineer.

Filed in triplicate with the Advisory Board of Army Engineers on San Francisco Water Supply, August 1, 1912.

The Mokelumne River, where it breaks out from the mountains and enters the San Joaquin Valley at Clements, has a drainage area of 630 square miles.

It commands about 200,000 acres of fertile valley land which will in the course of time be under irrigation.

The only valley canal now in service is the Woodbridge canal, which is low down on the stream and covers with constructed canals about 32,00 acres. Actual irrigation from this canal is reported to have been about 3000 acres.

In the mountains are a number of old ditches originally used for mining and now in service for domestic supply and irrigation, and also for power development. There are also some newer enterprises, such as the works of the Pacific Gas and Electric Company at Blue Lakes, and other reservoirs, and on the North Fork, where the Amador Canal has been made, in large part a source of supply for the power station at Electra and where the Standard Canal, also for the delivery of water to the same power station, has been constructed.

Some work of construction has also been commenced by the Sierra Blue Lakes Water and Power Company, which has submitted an offer to San Francisco to sell its properties or to construct water works for the city. This company owns lands and water rights and rights of way on the several branches of the Mokelumne River and outlines a project which, though feasible, if considered apart from the limit which it might be desirable to have placed upon the diversion of water from the river for use in remote territory, would yet be relatively expensive, due to the lack of favorable storage sites. Reservoir space, which is essential to any Sierra Nevada project, would have to be secured mainly in the narrow, deep canyons of the river by the construction of dams of unprecedented dimensions.

Irrigable Area Commanded by the River and its Requirements

The valley land, which is naturally dependent upon the flow of this river for irrigation water, extends from the old bed of Calaveras River northerly to some point between Dry Creek and the Cosumnes River. This is a region of great promise, but there has been very little concerted action thus far to make the river water which now flows to waste available for irrigation. Fertility of soil, a fair amount of rain, and topographic features, which make diversion of water near the base of the mountain more than ordinarily expensive, have apparently been the causes which have delayed the construction of large irrigation works, such as are now being constructed for the irrigation of lands on both sides of the Stanislaus River and as have come into use for the irrigation of the Turlock and Modesto irrigation districts on both sides of the Tuolumne River.

The discharge of Mokelumne River has been estimated for the period of 1879-1884 by the State Engineer of California and for the period 1905 to date by the United States Geological Survey. It has been estimated by comparison with the discharge of Stanislaus River for the additional period 1895 to 1900. The mean annual discharge is in round numbers 1,000,000 acre feet and the minimum for a single year is about one-fourth of this amount (1879-98).

By comparison of the monthly discharge during these periods with the probable ultimate irrigation requirement based on the diversion of 3 acre feet of water per year for each acre of land, it is found that there will ultimately be desirable an amount of reservoir space that can be made effective to the extent of 500,000 acre feet. It is also found that in four years out of five there would still be a surplus of flow to be wasted. If 300,000 acre feet of storage were available, the deficiency of supply would be so rare that no material injury to irrigation interests would result.

In view of these facts and because some additional shortage of reservoir capacity would not be fatal to the development of local resources, though measurably restricting these, it may be assumed that some water from this river could be spared for use in San Francisco.

A study of the effect of a diversion of 200,000,000 gallons per day for San Francisco, in addition to the probable ultimate irrigation requirement, was therefore made. This study indicates that it would then be desirable to have 1,000,000 acre feet of reservoir capacity available, and that with one-half of this amount there would be a deficiency of supply only in the rare case of such a critical period as that of 1897 to 1900.

So large an amount as 200,000,000 gallons will probably never be withdrawn to remote localities. But a diversion up to perhaps 60,000,000 gallons per day to supplement a water development such as that proposed from the Tuolumne may be regarded as a possibility.

Reservoirs and Reservoir Sites

The watershed of the Mokelumne River has already been thoroughly explored by power companies for storage facilities. The most available, though generally not large, reservoir sites are already occupied. If San Francisco or a metropolitan water district desires to develop a water supply from this river, it would be necessary to acquire prior rights or to quiet prior claims. On this river, as on other streams that come under consideration as possible sources of water, a diversion in such large amount as San Francisco should have at command can not be made without in a measurable, though limited, degree depriving some section of the State of some of its natural resources for the benefit of a great center of population.

The known storage possibilities on the Mokelumne River are small. Large reservoirs, when required, will probably have to be constructed in the river canyons, where high dams will be necessary. Table 9 of the report enumerates 15 reservoirs or reservoir sites, with an aggregate capacity of about 200,000 acre feet. The only two reservoirs of large capacity named in the table would require dams about 325 feet high, and these would be at sites that are not topographically very favorable and they would, therefore, be very costly.

Project Features

In order to have a basis for a cost estimate, a project has been outlined which conforms in some measure to the project outlined in the offer of the Sierra Blue Lakes Water and Power Company to the city. It is assumed that an initial development from the Mokelumne River would not exceed 60,000,000 gallons per day. This may, in fact, be the possible ultimate supply available for San Francisco from this source.

This water can probably be secured with least interference with established rights from the South Fork. By means of a high dam, storage in the amount of about 63,550 acre feet, or 20,708,000,000 gallons of water, can be secured. The reservoir will be long and narrow, but large enough to give the water opportunity to rid itself of any pathogenic germs which might reach it from a watershed in which there is some, though limited, human activity.

From this reservoir, by covered canal, the water can be conveyed to near Rich Gulch substantially on the route as projected by the Sierra Blue Lakes Water and Power Company and outlined in their statement describing the properties and rights which they offer to sell to the city.

From the point thus reached, the water would be dropped about 1275 feet to a power house, at an altitude of about 900 feet above sea level. From the wheels of the power house it would be delivered into the conduit that would convey it to San Francisco.

Railroad Flat Reservoir

The watershed naturally tributary to the Railroad Flat reservoir site has an area of 66 square miles. The normal or mean annual precipitation on this area, mostly in the form of snow, is 52 inches and the runoff in a year of normal rainfall is about 19 inches, or 66,000 acre feet. The runoff will range from a minimum of about 10,400 acre feet, in such seasons as 1897-1898, to a maximum of over 200,000 acre feet in such seasons as 1889-1890.

The annual delivery of 60,000,000 gallons of water per day, if constantly maintained, would require an annual supply of about 67,000 acre feet. This is far in excess of the minimum annual yield of the watershed which is tributary to Railroad Flat reservoir. It is just about the capacity of this reservoir if constructed with a dam 325 feet high. Unless reinforced by feed canals from other branches of the Mokelumne River, the South Fork will not be fully adequate to supply at all times 60,000,000 gallons of water per day. But, without any detail analysis, it can be stated as a fact that the periods during which there would be natural shortage would be so small a proportion of the time that, insofar as the water supply alone is concerned, the installation of the plant at the named capacity would still be justified, even though the circumstances might make future extension impracticable.

By a runoff study based on the known distribution of rainfall to a long series of years, it is found that in about 60 out of 100 years the yield of South Fork at Railroad Flat would, if regulated by an adequate reservoir, supply 60.000,000 gallons or more of water per year. In the remaining years there would be more or less shortage to be made good out of held-over storage. The shortage in these years, if distributed to the full period, would average between 8,000,000 and 9,000,000 gallons per year. Consequently, with storage adequate to equalize the annual flow in a year of normal runoff, it may be assumed that the actual yield one year with another would fall somewhere between 51,000,000 gallons and 60,000,000 gallons per day. At this capacity a Mokelumne River project as an auxiliary to a Tuolumne River project would be worth while.

Additional Water From Other Branches

Some attention has been given to the feasibility of adding to the yield from the South Fork water from the Middle and North Forks. From the North Fork water could be obtained by storage in a reservoir that could be created by a high dam. The capacity and cost of such a reservoir would depend upon the height of the dam. A high dam would be necessary. If one were carried out about as proposed by the Sierra Blue Lakes Water and Power Company, the reservoir and conduit to the South Fork would probably add $6,000,000 or $7,000,000 to the cost of a Mokelumne River project.

The watershed tributary to the selected site of the North Fork reservoir, above referred to, has an area of about 314 square miles, all mountain region. In this watershed are storage works of the San Francisco Gas and Electric Company. Due regard would have to be paid in the operation of any works on the North Fork to the rights of this company.

On the Middle Fork there is also some opportunity for storing water. One reservoir site high up on the North Fork of the Middle Fork was visited. A small amount of water from a tributary area of about 12 square miles can there be stored. It will be quite feasible to convey this water by short canal and tunnel from the Middle Fork across the divide into the projected Railroad Flat reservoir on the South Fork.

Cost Estimate. Outlines of Project for 60 Mil. Gals. Daily Pumped Near Altamont

The cost estimate presented herewith is restricted to the works which would be necessary to develop and deliver somewhere between 50,000,000 and 60,000,000 gallons of water per day from the South Fork of the Mokelumne River to San Francisco.

The conduit capacity is planned at 60,000,000 gallons per day.

As a basis for this cost estimate, it is assumed that there will be a diversion of water from the Middle Fork of the Mokelumne River by canal and tunnel with a capacity of 250 second feet, and that the water thus diverted will be delivered into the Licking Fork and the Railroad Flat reservoir. This diverting canal will have a length of about one mile and the tunnel a length of 2800 feet. An inexpensive diverting dam will be required on the Middle Fork. The canal would be an open conduit, as the water which it diverts would all rest in the South Fork (Railroad Flat) reservoir long enough to insure its wholesomeness.

The dam across the South Fork is projected as a gravity section concrete high structure rising 305 feet above the plane of low water and about 325 feet from the assumed lowest excavation in the river bed.

The crest length of the dam would be about 1010 feet. It is assumed that the stripping would average 10 feet in depth. The hillsides are soil covered and the bed rock, a hard greenstone, is more or less shattered where seen at the surface. Materials for concrete will have to be obtained by quarrying and crushing rock.

The suggested height of dam is desirable to secure adequate storage. With large storage there will be the least possible interference with vested water rights on the lower river and the service will be made fairly reliable.

Some study has been given to the question whether it would not be desirable to convey the water from Railroad Flat reservoir to the proposed power house at Rich Gulch in a pressure conduit, thereby adding to the power that could be developed. But although this seems feasible and could be economically desirable if power is marketed, it has seemed advisable for the present purpose to restrict the project solely to such features as are essential to the same as a water supply project.

The power generated at Rich Gulch, it is assumed, will be used solely in connection with this project to lift the water into the proposed tunnel at Altamont.

The location of the canal from Railroad Flat to Rich Gulch is on fairly favorable mountain slopes. It offers no serious difficulties. It has been surveyed by the engineer of the water and power company but not by the city.

Below the Rich Gulch power house, to Tracy, there has been no survey of the conduit lines; the location is a paper location known to be feasible. The most direct route has been indicated on the location map. If for any reason, as on account of the character of the material into which trenches would have to be cut or due to the too broken character of the ground, another route would prove more acceptable, the same, on a somewhat longer course, can be found by paralleling the railroad from near Valley Springs to Clements, from where the location would be on smooth valley floor. This alternate location has been explored and is known to be perfectly feasible.

Same as Grunsky-Manson Tuolumne Project Between Tracy and San Francisco

From a point near Tracy the conduit line to San Francisco will be the same as for the Tuolumne River, 60,000,000 gallons per day project, as reported on by Mr. Manson, as a modification of the writer's original suggestion.

The power station and pumping station on the proposed conduit line would be in substantial conformity with those reported on by Messrs. A. M. Hunt and Rudolph W. Van Norden, and their estimates of cost have been adopted for these features of the project.

For the conduit across the San Joaquin Valley a single line of 60-inch pipe has been projected. One pipe line is deemed adequate in this case, because any project from the Mokelumne

River should be considered as supplemental to a supply from the Tuolumne.

Project for 200 Mil. Gals. Daily With Pumping Near Altamont

The additional cost of a larger project, that is a project for the delivery of 200,000,000 gallons per day, is herein below indicated on the basis of the estimates which were made for the proposed 60,000,000 gallon unit.

No final study of so large a project has been made. If a cost estimate were wanted for comparison with such projects as the McCloud River project, the following modifications would require consideration:

The larger project would probably make the substitution ot concrete pressure pipe for steel pipe across San Joaquin Valley desirable. The pumping station would then be located at a lower elevation, probably at about 80 or 85 feet near Tracy. The elevation of the Altamont tunnel would be at about 600 feet and from the westerly end of the Altamont tunnel there could again be a concrete pressure conduit to near Dublin; then a tunnel under the ridge westerly to Palomares Creek and pressure pipe and tunnel through the Castro ridge to a point above Haywards, from which steel pipes and a submerged bay crossing from Alameda Point to Potrero Point in San Francisco would enable a delivery of water in San Francisco at an elevation of about 175 feet above mean sea level.

A route of this kind, which is open to the Tuolumne River as well as to the Mokelumne River project, has the disadvantage that it affords no nearby storage in large amount. No special study of its advantages or disadvantages, nor of the cost of construction, has been made.

It is not, however, to be overlooked when a final decision is rendered relating to the details of the development of any Sierra Nevada source of supply from the American River southward.

Probable Cost of Water Rights

The properties which the Sierra Blue Lakes Water and Power Company own, and the water rights and rights of way which this company claims, or has acquired, have been offered to the City and County of San Francisco for $6,000,000. This offer was made in 1911. (See report of the City Engineer on this offer. Mun. Reports, 1910-11, page 903.)

In view of this offer, it might appear proper to introduce into the cost estimate of a Mokelumne River water supply project an item of $6,000,000 for water rights, reservoir sites and lands. But it is believed that this asking price, being mainly for undeveloped water rights, is far in excess of what these rights and the real properties of the company could be acquired for, and the estimated cost of acquiring them has, therefore, been introduced into the cost estimate at a much lower figure.

MOKELUMNE RIVER WATER SUPPLY PROJECT.

Capacity 60,000,000 gallons per day delivered in San Francisco at about elevation 200.

DIVERSION DAM—MIDDLE FORK.....		$ 25,000
CONDUIT from Diversion Dam to Railroad Flat Reservoir, 5280 ft. open canal, 250 sec. ft. capacity at $6.00.......................$	31,680	
2800 ft. 7x7 tunnel at $30.00..............	84,000	115,000
RAILROAD FLAT RESERVOIR,		
Clearing 544 acres at $100................$	54,400	
Dam 476,840 cu. yds. concrete at $9.00......	4,291,560	
Stripping 41,800 cu. yds. at $1.00..........	41,800	4,387,760
CONDUIT from Railroad Flat to Forebay above Power House,		
60,720 ft. cut and cover at $5.60............$	340,032	
Waste Gates	11,500	351,532
FOREBAY		50,000
POWER PLANT—Rich Gulch, 1275 ft. Station Head, 2-4000 K. W. units complete with buildings and transformers as per designs and estimates of Bear Gulch Power Station for Tuolumne project by A. M. Hunt and R. W. Van Norden.....................		230,120
PIPE LINE, FOREBAY TO POWER HOUSE		79,000
TAILBAY		30,000
CONDUIT from Power House to point 3½ miles southwest of Valley Spring, 119,000 ft. + 5% = 125,000 cut and cover at $5.60...	700,000	
13,000 ft. 4½x6 concrete lined tunnels at $25	325,000	
Waste Gates, flumes......................	25,000	1,050,000
STEEL SIPHON to Altamont Pumping Station, Total weight, 100,157,000 lbs.		
30,600 ft. + 5% ¼ x 60-in. at $10.55.....$	338,971	
16,800 ft. + 5% 5/16 x 60-in. at 13.20.....	232,848	
21,200 ft. + 5% ⅜ x 60-in. at 15.85.....	352,821	
22,600 ft. + 5% 5/16 x 60-in. at 18.50.....	439,005	
34,000 ft. + 5% ½ x 60-in. at 21.15.....	755,055	
47,800 ft. + 5% 9/16 x 60-in. at 23.80.....	1,194,522	
79,200 ft. + 5% ⅝ x 60-in. at 26.40.....	2,195,424	
Anchorage, drains, etc., at $2.50............	622,650	
15,000-ft. trestle crossing Calaveras River, Mormon Slough, French Camp Slough, San Joaquin Marsh, etc., at $10.00............	150,000	
San Joaquin crossing, 3-36-in. submerged cast-iron pipes	50,000	6,331,296
TRANSMISSION LINE, Rich Gulch to Altamont, 3-phase 2-circuit tower line, 73 miles...		402,000

The following items are taken directly from the report of A. M. Hunt and R. W. Van Norden on the "Mechanical Equipment of the Tuolumne Project," dated October, 1911, except that 15 per cent is added for engineering and incidentals instead of 10 per cent. The estimate of land, water rights and rights-of-way are for the entire project.

RECEIVING RESERVOIR at pumping station, including outlets, valves and conduit to pump suctions	139,000
PUMPING STATION complete, including all equipment, buildings, pipe connections and auxiliaries	525,000

RIVETED PIPE, 34,000 ft. of double 48-in. riveted pipe, force main from pumping station, weight 13,408,500 lbs., including manholes, air valves and blowoff gates		804,510
CUT AND COVER TUNNEL from top of force main to summit tunnel, 18,500 ft. with capacity for 200,000,000 gallons daily (see note below)		287,500
TUNNELS, 3 line tunnels, 39,240 ft. total length, capacity 200,000,000 gallons daily (see note below)		1,373,400
RIVETED PIPE, mains connecting tunnels from summit to city line of San Francisco, 293,500 ft., double 50-in. riveted pipe, weight 117,850,836 lbs., including manholes, air valves, and blow-off gates		7,071,050
BAY CROSSING, submerged crossings of slough and bay, three 36-in. galvanized steel pipes, total length 6700 ft., with gates and connections		622,850
BRIDGES, TRESTLES, ETC., Bridges, trestles, culverts and special supports, line from Altamont summit to city line		435,000
		$24,310,698
ENGINEERING AND CONTINGENCIES, 15 per cent		3,646,605
TOTAL COST OF STRUCTURES		$27,957,303
LANDS AND RIGHTS, Reservoir lands and water rights	$2,000,000	
Rights-of-way, pumping station site, etc., legal cost	800,000	2,800,000
		$30,757,303

Note—The cut and cover tunnel and the three lined tunnels on a basis of 60,000,000 gallons would probably reduce these amounts to $103,500 and $980,000, respectively, a total reduction of $577,400.

PROJECT FOR THE DEVELOPMENT OF 200,000,000 GALLONS OF WATER FROM THE MOKELUMNE RIVER.

If the initial development of 60,000,000 gallons were made with a view of future development of the project to 200,000,000 gallons capacity, then the cut and cover conduit and tunnels would, in all probability, be built to the latter capacity in the first place. This would then have increased the cost of items enumerated in the foregoing estimates by the following amounts:

CUT AND COVER CONDUIT, 185,720 ft. at $10.00 (increased cost per ft.)	$ 1,857,200
TUNNELS, 13,000 ft. at $10.00 (increased cost per ft.)	130,000
TOTAL	$1,987,200
Making the total cost of the initial 60,000,000 gallon project then	$32,744,503

The following estimate of cost of a 200,000,000 gallon supply from this source is based then on the latter amount to which has been added the cost of constructing the North Fork reservoir and diverting tunnel, together with the cost of increasing the capacity of the remaining parts of the system as enumerated.

MOKELUMNE RIVER WATER SUPPLY PROJECT

Capacity 200,000,000 gallons per day delivered in San Francisco at elevation 200.

INITIAL 60,000,000 GALLON PROJECT		$32,744,503
NORTH FORK RESERVOIR,		
Clearing basis 736 acres at $100	$ 73,600	
Concrete dam, 325 ft. high, 1120 ft. crest length, 605,480 cu. yds. at $9.00	5,449,320	
Stripping 49,800 cu. yds. at $1.00	49,800	5,572,720
TUNNEL from North Fork Reservoir to Middle Fork near mouth of the North Fork of the Middle Fork, 200,000,000 gallons capacity (6 x 7) 40,128 ft. at $30.00		1,203,840
POWER HOUSE, Additional Installation, 16,000 K. W.		460,240
PIPE LINE to Power House, 2 additional lines		158,000
STEEL SIPHON to Altamont, 2 additional 60-in., laid complete		12,662,582
TRANSMISSION LINE, additional capacity, (obtained either by increase of copper at 60,000 volts or increase of voltage to 100,000 volts with some increase of copper)		503,200
ALTAMONT PUMP STATION, 140,000,000 gallons additional capacity		1,225,000
FORCE MAIN, 4 additional lines 48-in pipe (34,000 ft. each)		1,609,020
		$56,139,105
MAINS from tunnels at Altamont summit to San Francisco County line, 4 additional lines 50-in. pipe, 293,000 ft.		14,142,100
BAY CROSSING, 6 additional lines of 36-in. galvanized steel pipe 6700 ft. long, with gates and connections		1,245,700
BRIDGES, TRESTLES AND SUPPORTS for additional lines from Altamont summit to San Francisco		870,000
		$72,396,908
Engineering and Contingencies, 15 per cent on the additional expenditure of $41,639,602		6,245,940
TOTAL COST of 200,000,000 Gallon Development		$78,642,845

Offer of the Sierra Blue Lakes Co.

The Sierra Blue Lakes Water and Power Company offer to San Francisco certain properties on the Mokelumne River, supplemented by an old ditch which diverts water from the South Fork of the Middle Fork of the Cosumnes River.

The Sierra Blue Lakes Company is the owner of the old Clark ditch, which heads on the South Fork of the Mokelumne River at Blue Mountain and was constructed about fifty-five years ago, with a capacity of about 12 second feet (600 miners inches) for the supply of water to mining properties and other interests in the vicinity of Glencoe and Rich Gulch. The water and power company owns also or controls lands on the South Fork of Mokelumne River at Railroad Flat and on the North Fork of the Middle Fork of Mokelumne River, and holds a reservoir right of way in the Stanislaus Forest Reserve on the North or Main Fork of the Mokelumne River. The company has also under its control and offers a reservoir and canal system on the South Fork of the Middle Fork of the Cosumnes River. To these properties the company adds certain other rights of way and undeveloped water rights. The company claims to be in position either to transfer to the city a good title to all the water that the city would require, together with the necessary storage sites and rights of way, or to construct and turn over to the city a system of water works with a conduit capacity of 60,000,000 gallons per day, completed to Dumbarton Point, for $20,000,000.

The project is described by Mr. C. M. Burleson, the Chief Engineer of the Water and Power Company, in a report already on file as part of the proceedings in these water supply investigations, and need not be repeated in detail.

In reference to this project and offer, it may be stated that such works as the city of San Francisco would require for the immediate delivery of 60,000,000 gallons per day of acceptable water from the Mokelumne River, with an ultimate capacity of 200,000,000 gallons per day, cannot be carried out for $20,000,000—i. e., with delivery in San Francisco.

That the project as outlined by its proponents has some merit will appear from what has already been said about the Mokelumne River as a source of water. It is also apparent, as the result of an inspection on the ground, that actual work has been done to make good and hold the water rights which the Water and Power Company claims. On the South Fork below the mouth of the Licking Fork a concrete dam has been commenced. It is at present too low to command any storage. The reservoir site above this dam up to about 300 feet contour and for a mile or more up stream has been cleared of brush and timber. A small force is kept at work preparing additional foundations at the dam site.

A part of the diverting canal from the Middle Fork of the South Fork has been constructed and of the 2800 feet of tunnel on the conduit line from the Middle Fork to the South Fork about 300 feet (at the south end) have been constructed.

At the mouth of Blue Creek on the North Fork, which is in the company's reservoir site, a camp is maintained and surveyors were found at work in July, 1912, continuing necessary surveys. Good trails have been constructed from this camp up to the south side summit and to the dam site, which is about a mile below the mouth of Blue Creek.

At Case Valley, on the South Fork of the Middle Fork of Cosumnes River, about a mile below the point on the Geological Survey sheet marked "Tars Mill," there is a loose rock dam, or rather part of a loose rock fill. Portions of this dam have been washed out. It is not at present effective as a dam and is not of such a character that it would be of any value in the construction of a high dam (100 or 200 feet high) at this point. It would probably be easier to construct a dam if the old structure had never been commenced.

The head of the Case Valley or Oleta ditch is some 3 or 4 miles below Case Valley. It receives its water in part from the South Fork of the Middle Fork of Cosumnes River and in part from creeks which it creates. It was dry when examined in July, 1912, and has the appearance of an abandoned mining ditch.

Its location is such that there is no question about the feasibility of carrying its water on the route suggested by the Water and Power Company, and using it for power at the proposed Rich Gulch power house.

The Case Valley reservoir is an element of minor importance, and practically negligible in connection with a water supply for San Francisco. It commands a watershed of only 6 square miles and the small amount of water which it would add to such a supply out of storage and natural flow as would come from about 300 square miles of higher mountain area to the North Fork of the Mokelumne Reservoir site would hardly justify its addition to a water works system.

Project features of the proposed water works system offered to the city by the Sierra Blue Lakes Water and Power Company would undoubtedly be materially modified if the city formulates rigid requirements. Storage on the South Fork and on the North Fork would require dams of unusual magnitude. The cubical contents of a gravity section masonry dam 325 feet high at the North Fork site would be 605,000 cubic yards; and at the South Fork or Railroad Flat site a dam of similar character and height would contain 476,000 cubic yards of masonry.

The Blue Lakes are located close by the crest of the Sierra Nevada. Their tributary watershed is only about 5 square miles. The Pacific Gas and Electric Company and the Sierra Blue Lakes Water and Power Company both appear to have certain rights in the waters of the lakes. As reservoirs on a municipal system they would have but small value.

Although the water rights which the Sierra Blue Lakes Water and Power Company offers to the city are mainly undeveloped rights, some of the properties which this company claims to control would have value to the city if a Mokelumne River project were to be carried out, and this fact has been taken into account, as already explained, in preparing the cost estimate.

Quality of Water from Mokelumne River

The quality of the water obtainable from the Mokelumne River is good. If taken from a large reservoir such as proposed for Railroad Flat and thereafter kept in a close conduit, it would be safe to use without filtration.

If diverted from the stream below the proposed power house at Rich Gulch or below the power house at Electra, it should be filtered before using or should be delivered into some nearby reservoir, such as the Crystal Springs, before being delivered to consumers. (See Water Supply Paper, No. 237, of the United States Geological Survey.)

Mr. Grunsky's Conclusions

Based upon the situation as herein outlined for the Mokelumne River as a source of water for the City and County of San Francisco, the following conclusions seem to be justified:

(1) The occupation and use by San Francisco of any large amount of reservoir space in the watershed of the Mokelumne River will interfere to a material extent with possible ultimate local development of natural resources.

(2) The Mokelumne River should not be regarded as available to supply the full amount of water that will undoubtedly be required in the future, from remote sources, for use in the bay regions. The limit may, for the present, be placed at about 60,000,000 gallons per day.

(3) The cost of storage in large quantity on the Mokelumne River is relatively high.

(4) Any project for the supply of water to San Francisco from the Mokelumne River would probably interfere with vested rights to such an extent that large initial cost for necessary rights and lands should be assumed.

(5) The Mokelumne River may be regarded as a source of water which could, if this be necessary, be made to supplement to a limited degree, a supply from other sources.

(6) The Mokelumne River, apart from any interference with local interests, is less available by reason of topographic and hydrographic conditions as a source of water, than either the Stanislaus or Tuolumne Rivers.

(7) There would probably be less concerted opposition by local interests to the taking of a limited amount of water from the Mokelumne River than from the Stanislaus River or from the Tuolumne, where the irrigation interests are already organized.

(8) The proposition of the Sierra Blue Lakes Water and Power Company should not be regarded as one that could be definitely considered in its present form. It would have to be based on carefully prescribed requirements which would, no doubt, lead to material modifications thereof.

GRAVITY FLOW PROJECT FOR SUPPLY FROM MOKELUMNE RIVER FOR COMPARISON WITH THE TUOLUMNE RIVER PROJECT.

(Pumping at Altamont eliminated.)

In order to permit a better comparison with the Tuolumne River project as outlined by Mr. J. R. Freeman the following modifications of the project and new cost estimates have been made.

Instead of conveying the water to a pumping station near Tracy it would be carried from the proposed power house at Rich Gulch in a steel concrete lined pipe to the east end of the Tesla Tunnel of the Freeman project.

The length of the conduit from Rich Gulch to Tesla Tunnel would be about 416,000 feet. The available fall in this distance would be from 875 feet at the power house to 430 feet at the Tesla tunnel, or 445 feet. The hydraulic grade line would, therefore, have a fall of 1.07 feet in 1000 feet.

The fall would probably be uniformly distributed to the entire conduit line. On this assumption it is found that the net diameter of a concrete lined conduit should be 63 inches for a delivery of 60,000,000 gallons per day and 96 inches for a delivery of 200,000,000 gallons per day.

The unit prices applied to the main portion of the conduit, the steel siphon across the San Joaquin Valley have been modified to conform to the unit prices adopted by Mr. Freeman. In other respects the cost estimates is the same as submitted for the original project. The further studies that would have been necessary to apply Mr. Freeman's conclusions as to cost to the upper portion of the works could not be made for lack of time.

It is also to be noted that in the modification of this project the scheme for power development at Rich Gulch has been retained. The power there developed would not be required at Altamont, but would be available for use in pumping to higher levels in San Francisco, or for other uses.

The cost of a transmission line from Altamont to San Francisco has, therefore, been added, and the available power is to be considered as an asset to be taken into account in the consideration of this project.

ESTIMATE OF COST, MODIFIED PROJECT, MOKELUMNE RIVER.

60,000,000 gallons per day. Delivery into east end of Tesla Tunnel.

Items as enumerated for original 60,000,000 gallon project down to a point about 3½ miles southwest from Valley Springs at the head of the proposed steel siphon		$6,319,092
TRANSMISSION LINE, Rich Gulch to San Francisco, 3-phase, 2-circuit tower line, 155 miles		852,500
CONCRETE LINED STEEL SIPHON, 66 inches in diameter (63 inches clear) from a point 3½ miles southwest from Valley Springs to the east end of Tesla Tunnel:		
12,500 ft. ¼-in., at $ 6.88	$ 86,000	
22,500 ft. ⅜-in., at 10.35	233,000	
43,000 ft. ½-in., at 13.75	592,000	
206,000 ft. ⅝-in., at 17.25	3,553,000	
	$4,464,000	
Concrete lining, 284,000 ft., at $1.35	$384,000	

Excavation and backfill, 284,000 ft., at 75 cents	213,000	
Crossing of wet ground, swamp, etc., 15,000 ft., at $2.80	42,000	
Crossing of San Joaquin River, Calaveras River, Mormon Slough, etc.	60,000	
Add for overhead charges, contractor's profit and contingencies not covered by usual allowance of 15 per cent	1,032,600	6,195,600
		$13,367,192
Engineering and contingencies, 15 per cent		2,005,080
		$15,372,272
Lands and Rights—Reservoir lands and water rights	$2,000,000	
Rights of way, legal cost, etc.	800,000	2,800,000
Total estimated cost of project for the delivery of 60,000,000 gallons of water per day from Mokelumne River into Tesla Tunnel, including the generation of 8,000 K. W. power at Rich Gulch and transmission to San Francisco		$18,172,272

ESTIMATE OF COST, MODIFIED PROJECT, MOKELUMNE RIVER.

200,000,000 gallons per day. Delivery into east end of Tesla Tunnel.

Items as enumerated for original 60,000,000-gallon project down to a point 3½ miles southwest from Valley Springs at the head of the proposed steel siphon, with $1,987,200 added for increased cost of tunnels, etc., cut and cover conduit, and $460,240 for additional power (total power installation, 24,000 K. W.)		$8,766,532
NORTH FORK RESERVOIR and tunnel to Middle Fork		6,776,560
TRANSMISSION LINE, Rich Gulch to San Francisco		1,922,000
CONCRETE LINED STEEL SIPHON, 99 inches diameter (96 inches clear), from a point 3½ miles southwest from Valley Springs to Tesla Tunnel:		
5,400 ft. ¼-in., at $10.40	$ 56,200	
7,200 ft. ⅜-in., at 15.65	113,000	
13,000 ft. ½-in., at 20.80	270,000	
22,400 ft. ⅝-in., at 26.10	585,000	
29,000 ft. ¾-in., at 31.20	905,000	
86,000 ft. ⅞-in., at 36.40	3,135,000	
121,000 ft. 1-in., at 41.60	5,050,000	
	$10,114,200	
Concrete lining, 284,000 ft., at $1.94	550,000	
Excavation and backfill, 284,000 ft., at $1.50	426,000	
Crossing of wet ground, swamp, etc., 15,000 ft. at $4.10	61,500	
Crossing of San Joaquin River, Calaveras River, Mormon Slough, etc.	100,000	
Add for overhead charges, contractor's profit, and other items not covered by the usual allowance of 15 per cent	2,250,340	$13,502,040
Engineering and contingencies, at 15 per cent		4,645,070
		$35,612,202
Lands and Rights—Reservoir lands and water rights	$2,000,000	
Rights of way, legal cost, etc.	800,000	2,800,000
Total estimated cost of project for the delivery of 200,000,000 gallons of water per day from Mokelumne River into Tesla Tunnel, including delivery of power (24,000 K. W.) at Rich Gulch Power House, to San Francisco		$38,412,202

Appendix No. 19

GAUGINGS AT AND NEAR THE PROPOSED SAN FRANCISCO DAM SITES ON THE TUOLUMNE RIVER, ELEANOR AND CHERRY

The data obtained under the supervision of the City Engineer Marsden Manson, during the past two years or more of stream gaugings in the Hetch Hetchy Valley at Lake Eleanor and at Cherry Creek are so valuable and important in demonstrating the quantity of water which can be depended on from this watershed and so valuable for connecting up the yield at Hetch Hetchy, Eleanor and Cherry with that gauged for many years past at La Grange, that the daily record is published in full for convenience of future reference.

Also the record of the previous gaugings made while the Heach Hetchy and Eleanor sources were under examination by City Engineer Grunsky eleven years ago are repeated for convenient comparison.

The measurements under Mr. Manson's supervision were made by experienced engineers, who lived continuously in cabins built by the city close to the work, the methods employed were the standard methods of the U. S. Geological Survey, and the records are entitled to full confidence in their accuracy.

DISCHARGE MEASUREMENTS MADE ON TUOLUMNE RIVER IN HETCH HETCHY VALLEY IN 1899 AND 1901.

(By the U. S. Geological Survey in 1899; by the City Engineer in 1901.)

Date, 1899.	Gauge Height (Feet)	Area of Section (Sq. Ft.)	Mean Velocity (Feet per Second)	Discharge (Sec. Ft.)
July 31	....	......	....	* 238.00
Aug. 5	....	......	....	* 230.00
Aug. 12	....	......	....	* 130.9
Aug. 19	....	......	....	* 100.8
Aug. 23	....	......	....	* 68.5
1901				
June 29	36.00	2027.00	3.76	*7621.00
July 4	30.00	1654.6	2.00	*3296.00
July 12	26.1	1413.00	1.92	*2720.00
July 21	24.17	1295.00	1.46	*1886.00
July 29	21.5	1108.00	1.04	*1160.00
Aug. 2	20.33	1036.00	1.10	*1137.4
Aug. 13	15.70	228.00	2.07	† 472.2
Aug. 25	13.28	99.88	2.32	† 231.3
Aug. 29	12.93	86.17	2.21	† 190.45
Sept. 5	12.65	21.00	2.20	† 155.66
Sept. 14	12.42	40.50	1.91	† 77.51
Sept. 20	12.32	32.00	2.06	‡ 66.12
Sept. 28	13.11	54.50	2.65	‡ 144.68
Oct. 5	12.92	41.20	2.80	§ 115.64
Oct. 11	12.60	34.50	2.94	** 87.57
July 13	1.20	461.55	4.00	††1848.56
Aug. 26	....	75.60	2.10	†† 160.00
Sept. 28	....	55.00	1.86	†† 102.39
Oct. 11	....	45.70	1.33	†† 59.62

* At dam site.
‡ Between dam site and ford.
** 50 feet below ford.
† 1000 feet above dam site at ford.
§ 1000 feet above cable ford.
†† Above Rancheria Creek.

RATING TABLE FOR TUOLUMNE RIVER IN HETCH HETCHY VALLEY—1901.

Height on Gauge.	Discharge (Sec. Ft.)	Height on Gauge.	Discharge (Sec. Ft.)
12 feet	50	24 feet	1900
12.5 "	100	26 "	2320
13 "	140	28 "	2920
14 "	190	30 "	3650
16 "	405	32 "	4580
18 "	680	34 "	5900
20 "	1000	36 "	7620
22 "	1400		

The gauging station is located at the outlet of Hetch Hetchy Valley. The deep gorge is partly refilled with sand, giving opportunity for change.

Note: The above data are from page 42 of "Reports on the Water Supplies of San Francisco, 1900 to 1908, inclusive," published by authority of the Board of Supervisors, 1908.

Also found in the U. S. Water Supply Bulletin No. 81, pages 381-2, and U. S. Water Supply Bulletin No. 66, page 147.

"A gauging station was established at this point (Hetch Hetchy dam site) May 30, 1901, by J. B. Lippincott, for the City of San Francisco," quoted from U. S. Water Supply Paper No. 81, page 381.

The above data are the bases of the estimates for May, June, July, August, September and October, 1901.

DISCHARGE AT HETCH HETCHY DAM SITE IN 1901 FROM GAGE HIGHT AND RATING CURVE

Date	May	June	July	Aug.	Sept.	Oct.
1		*1550	3650	*1122	*125	*142
2		1900	3130	1066	*121	*141
3		*1900	2376	* 980	*119	*138
4		*1900	3650	* 911	*115	*136
5		*1900	3650	* 838	112	133
6		2000	*2920	* 762	*108	*128
7		2000	*2920	* 682	*104	*125
8		*2320	*2100	* 672	*101	*121
9		2320	*2100	* 610	* 98	*116
10		*2600	1920	* 542	* 95	*112
11		2920	2320	* 480	* 95	108
12		*2920	2348	* 415	* 95	*106
13		3270	2488	370	* 95	*105
14		3270	2320	* 356	95	*103
15		*3650	2000	* 336	* 93	*100
16		*4030	*2320	* 315	* 92	
17		*3650	*2000	* 294	* 92	
18		*3650	*1900	* 270	* 90	
19		4580	1900	* 250	* 87	
20		*4580	*1900	* 226	86	
21		*4580	1940	* 204	* 92	
22		5150	1980	* 190	*102	
23		*3650	*1900	* 176	*111	
24		3650	*1700	* 168	*123	
25		3650	*1700	156	*128	
26		4330	*1400	* 150	*133	
27		3822	*1400	* 146	*141	
28		6440	*1300	* 147	147	
29		7620	1300	135	145	
30	4751	4430	*1200	* 130	143	
31	4580		*1200	* 127		
Total Sec. Ft.	9331	104282	66932	13226	3283	1813
Total Mill. Galls.	6028	67334	43238	8544	2121	1171

*Indicates estimated gage hight.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, TUOLUMNE RIVER. AT HETCH HETCHY CABIN ABOVE FALLS CREEK AND AT HETCH HETCHY DAM SITE.

Watershed Area Above Dam Site 463 Square Miles. Watershed Area, Falls Creek, 46 Square Miles.

1910.

Date.	September.	October.	November.	December.	
	H.H. Cabin.	H.H. Cabin.	H.H. Cabin.	H.H. Cabin.	H.H. Dam Site.
1			M 67	D 72	D 102
2			M 65	M 68	M 89
3			M 64	D 131	D 210
4			D 61	M 142	M 208
5			D 58	D 133	D 212
6			M 54	M 124	M 157
7			M 53	D 193	D 247
8			D 38	M 214	M 276
9			M 38	D 179	D 217
10		M 34	D 53	M 398	D 489
11		M 67	D 56	D 392	M 512
12	30.98	M 151	M 97	M 253	D 342
13		M 126	M 95	D 179	D 260
14		M 104	D 87	M 156	M 224
15		M 126	D 83	D 146	D 214
16		M 144	M 71	M 115	M 169
17		M 126	D 67	D 126	D 140
18		M 146	M 87	D 112	D 138
19		M 138	M 92	M 105	M 151
20		M 129	D 87	D 109	D 140
21		M 122	M 104	M 91	M 120
22		M 121	D 104	D 95	D 120
23	92.47	M 119	M 92	M 89	M 125
24	88.09	M 109	D 119	D 87	D 120
25		M 102	M 102	M 84	M 122
26		M 95	M 83	D 66	D 110
27		M 95	M 72	D 66	D 108
28		M 83	D 88	M 68	M 96
29		M 76	M 70	D 72	D 110
30		M 77	M 72	D 62	D 103
31		M 77		M 64	D 102
Total Sec. Ft.	211.54	2367	2279	4191	5733
Tot. Mil. Gals.	136.65	1529	1472	2707	3704

September gagings at Cabin, above Falls Creek.

Hetch Hetchy Notes.

The difference between discharge at Cabin and that at dam site comes principally in the flow of Falls Creek watershed above dam, 463 sq. miles; above Falls Creek, 46 sq. miles.

D Denotes that quantity is taken from gage height and discharge curve.

M Denotes actual gaging by current meter.

DC Denotes estimate of quantity made from continuous chart of recording gage and discharge curve.

MC Denotes same as DC, except that an actual meter-gaging was also made.

E Denotes estimate; no gaging.

In 1912, January 1 to January 15, river frozen over; meter readings unreliable; flow estimated at 90 second feet.

In 1912, March, gagings at Cabin and Falls Creek are all meter measurements except on 21st, which is from curve.

In 1912, April, June, inclusive, gage rod at Cabin and dam site not read simultaneously, therefore, Falls Creek separate flow can not be figured from these precisely.

In 1912, April, June, inclusive, all measurements of quantity for this period are by current meter.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, TUOLUMNE RIVER, AT HETCH HETCHY CABIN ABOVE FALLS CREEK, AND AT HETCH HETCHY DAM SITE.

Watershed Area Above Dam Site 463 Square Miles.

1911.

	January		February		March		April		May		June	
Date	H.H. Cabin	H.H. Dam site	H.H. Cabın	H.H. Dam site	H.H. Cabin	H.H. Dam site	H.H. Cabin	H.H. Dam site	H.H. Cabin	H.H. Dam site	H.H. Cabin	H.H. Dam site
1	D 58	D 73	D 342	DE 977	M 231	D 351	M 1649	M 1862	M 1707	MC 2047	D 2200	DC 2533
2	D 54	D 70	D 345	DE 860	M 287	D 365	M 1557	2340	M 1608	MC 2093	D 2770	DC 3417
3	M 57	M 76	M 749	M 978	M 517	D 550	M 1773	M 2143	M 1907	DC 2411	D 3955	DC 4961
4	D 62	D 80	D 770	D 978	M 543	M 618	D 1375	D 1560	D 2360	MC 3187	M 5332	MC 6540
5	D 56	D 73	M 593	D 688	M 479	D 620	D 1620	D 1862	M 3023	DC 3832	M 6474	MC 7462
6	M 56	M 73	D 546	D 645	M 425	D 557	M 1254	D 1560	M 2012	MC 2610	M 7253	MC 8067
7	D 54	D 73	M 482	M 639	M 578	M 638	M 1092	M 1188	D 1890	DC 2325	M 4847	DC 6771
8	D 54	D 70	D 452	D 575	M 669	D 774	M 1103	D 1220	D 1890	DC 2360	D 4740	DC 5618
9	D 214	D 272	D 430	D 556	M 657	D 765	M 1011	D 1580	D 2012	MC 2410	D 5865	DC 6473
10	M 136	M 209	M 450	M 550	M 528	M 953	D 1000	M 1149	M 1917	DC 2310	M 6655	MC 7987
11	D 104	D 135	M 396	D 515	M 524	D 940	M 862	D 1025	D 2220	DC 2300	M 8152	MC 9703
12	D 126	D 140	M 379	D 512	M 533	D 572	M 771	D 980	D 2440	MC 3132	M 8969	MC 10307
13	M 165	M 217	M 434	M 537	M 513	D 590	M 661	D 900	M 2110	DC 2770	M 9411	MC 10647
14	D 156	D 226	M 383	D 512	M 504	D 585	D 705	D 870	D 2085	DC 2656	M 7282	DC 9750
15	M 179	M 269	M 373	D 630	M 525	M 597	D 710	D 880	D 1750	MC 2110	M 8038	MC 9797
16	D 144	D 215	M 361	M 401	M 581	D 630	D 750	D 930	D 1555	DC 1790	M 8519	MC 9981
17	D 156	D 226	M 342	D 444	M 668	D 774	M 900	M 1018	D 1495	DC 1720	M 9459	MC 10593
18	M 189	M 230	M 345	M 396	M 735	M 865	D 1090	D 1310	M 1490	MC 1773	M 9744	MC 11423
19	D 144	D 215	M 342	D 444	M 716	D 840	D 1280	D 1530	M 2149	MC 2602	D 9070	DC 10800
20	D 812	D 990	M 319	D 406	M 758	D 880	D 1290	D 1555	M 2650	MC 3417	D 9156	DC 10363
21	M 547	M 741	M 295	M 342	M 719	D 850	D 1290	D 1550	M 3076	MC 4300	M 8868	DC 9868
22	M 360	M 427	M 294	D 370	M 754	M 933	D 1485	M 1746	M 4009	MC 5370	D 7556	MC 8190
23	D 253	D 338	M 316	D 406	M 961	D 1145	M 1917	MC 2310	M 5100	MC 6340	M 5431	DC 6880
24	D 709	D 810	M 307	D 392	M 842	D 1060	M 2110	MC 2740	M 4612	MC 5743	M 4650	DC 5143
25	M 709	D 805	M 288	M 339	M 928	M 1090	M 2366	MC 3030	M 3383	MC 4303	M 4362	MC 6077
26	M 462	D 562	M 251	D 346	M 969	D 1165	M 2543	DC 3427	M 2699	MC 3420	D 5865	DC 7260
27	M 376	D 461	M 250	D 346	M 962	D 1170	M 1829	MC 2527	M 2843	MC 3600	D 7280	MC 8438
28	D 342	D 450	M 228	M 308	M 1083	M 1297	D 1525	MC 1903	M 3009	MC 3920	D 6925	DC 7572
29	M 4424	E 5363			M 1194	D 1440	M 1348	MC 1700	M 3161	MC 3955	D 5700	DC 6840
30	M 5890	E 8510			M 1328	M 1566	M 1431	MC 1821	D 2650	DC 3557	D 4810	MC 6280
31	M 2839	E 4002			M 1551	D 1766			D 2360	DC 2791		
	*19887	26401	11062	15092	22262	26946	40297	50216	77172	97154	199338	235741
	**12847	17055	7146	9749	14381	17407	26032	32440	49853	62761	128772	152289

* Totals Sec. Ft. ** Totals Mill. Galls.

DAILY RUN-OFF IN CUBIC FEET PER SECOND TUOLUMNE RIVER, AT HETCH HETCHY CABIN ABOVE FALLS CREEK AND AT HETCH HETCHY DAM SITE AND OF FALLS CREEK.

1911.

Date	July		August		September		Total H. H. Dam Site. Sum of Falls Creek and Cabin
	H. H. Cabin	Dam Site	H. H. Cabin	Dam Site	H. H. Cabin	Falls Creek	
1	M 4564	DC 5420		1462	M 244.72	M 25.83	270.55
2	D 4775	DC 5940		1325	M 206.44	M 21.48	227.92
3	D 5525	MC 6587		1260	D 206.44	D 21.48	227.92
4	M 6457	DC 6107		M 972	D 173.17	D 15.63	188.80
5	D 5790	DC 6217		910	M 173.17	M 15.63	188.80
6	D 6300	MC 7292		805	D 173.17	D 15.63	188.80
7	M 5224	DC 7216		670	M 134.42	D 15.63	150.05
8	D 5070	MC 6798		M 601	D 134.42	D 15.63	150.05
9	D 4820	DC 5300		610	D 111.77	D 6.39	118.16
10	D 4820	DC 5547		645	M 111.77	M 6.39	118.16
11	D 4500	MC 6007		685	D 111.77	D 6.31	118.08
12	D 4820	DC 5459		M 707	M 108.64	M 6.35	114.99
13	D 4580	DC 5270		652	D 108.64	D 6.35	114.99
14	M 4597	DC 6290		585	D 108.64	D 6.35	114.99
15	D 6040	DC 6583		530	D 83.56	D 3.02	86.58
16	D 5540	DC 6037		471	M 83.56	M 3.02	86.58
17	D 5700	DC 5397		415	D 83.56	D 3.02	86.58
18	D 4895	DC 5393		390	D 83.56	D 3.02	86.58
19	D 3960	DC 5173		382	D 83.56	D 3.02	86.58
20	D 3350	MC 4253		318	D 71.51	D 2.88	74.39
21	D 2605	DC 3323		314	M 71.51	M 2.88	74.39
22	D 2510	DC 2715		310	M 87.12	M 6.31	93.43
23	D 2465	DC 2597		306	M 145.14	M 7.21	152.35
24	D 2605	DC 2570		302	M 110.89	M 3.05	113.94
25	D 2060	MC 2480		297	M 89.52	M 3.18	92.70
26	D 1680	DC 2203	M 255.55	M 290	M 85.09	M 3.12	88.21
27	D 1595	DC 2100	D 255.55	M 290	M 72.62	M 3.23	75.85
28	D 1575	DC 2030	D 255.55	270	M 67.10	M 2.99	70.09
29	D 1500	DC 1815	M 249.45	M 270	M 59.30	M 2.88	62.18
30	D 1360	DC 1647	D 249.45	270	M 72.18	D 2.88	75.06
31	D 1220	DC 1560	D 249.45	270			
Total Sec. Ft.......	122502	143321		17584	3456.96	240.79	3698.
Total Mill. Galls....	79136	92585		11359	2233.	156.	2389.

1911.

Date	October			November.			December.		
	H. H. Cabin	Falls Creek	Total H. H. Dam Site Sum of Falls Creek and Cabin	H. H. Cabin	Falls Creek	Total H. H. Dam Site Sum of Falls Creek and Cabin	H. H. Cabin	Falls Creek	Total H. H. Dam Site Sum of Falls Creek and Cabin
1	M 161.69	M 7.30	168.99	M 51.53	E .31	51.84	D 49.13	D 3.22	52.35
2	M 102.55	M 6.04	108.59	D 51.53	E .31	51.84	D 49.13	D 3.22	52.35
3	D 87.12	D 6.04	93.16	M 53.09	E .31	53.40	M 49.13	D 3.22	52.35
4	M 90.49	M 5.78	96.27	D 46.29	E .31	46.60	D 49.13	D 3.22	52.35
5	M 84.41	M 5.26	89.67	M 55.48	E .31	55.79	D 49.13	D 3.22	52.35
6	D 83.56	M 4.81	88.37	M 53.40	E .31	53.71	D 49.13	D 3.22	52.35
7	M 76.89	M 4.15	81.04	D 53.40	E .31	53.71	D 49.13	D 3.22	52.35
8	D 66.95	D 4.15	71.10	M 44.71	E .31	45.02	D 38.02	D 3.22	41.24
9	D 84.41	D 4.15	88.56	D 44.71	E .31	45.02	D 38.02	D 3.22	41.24
10	M 89.18	M 4.28	93.46	M 102.39	M 6.97	109.36	M 38.02	D 3.22	41.24
11	D 76.89	D 4.28	81.17	M 55.86	D 6.97	62.83	M 40.76	M 2.81	43.57
12	M 70.96	M 3.63	74.59	M 51.43	M 6.31	57.74	D 40.76	D 2.60	43.36
13	M 73.07	M 3.87	76.94	M 62.04	D 6.31	68.35	D 28.04	D 2.39	30.43
14	D 73.07	D 3.87	76.94	D 62.04	D 6.31	68.35	M 28.04	M 2.17	30.21
15	M 70.63	M 2.66	73.29	M 74.61	D 6.97	81.58	D 28.04	D 2.18	30.22
16	D 70.63	D 2.66	73.29	M 78.34	M 8.08	86.42	M 28.65	D 2.19	30.84
17	M 57.19	M 2.16	59.35	M 79.90	D 8.08	87.98	D 28.65	D 2.21	30.86
18	M 56.51	D 2.16	58.67	M 75.23	M 6.60	81.83	M 27.56	D 2.22	29.78
19	D 56.51	M 1.85	58.36	D 79.90	D 6.60	86.50	D 27.56	D 2.23	29.79
20	M 53.53	M 1.01	54.54	D 75.23	M 6.17	81.40	D 40.76	D 2.24	43.00
21	D 53.53	D 1.01	54.54	D 75.23	D 6.17	81.40	D 23.28	D 2.25	25.53
22	M 51.66	D 1.01	52.67	62.04	D 6.17	68.21	M 23.28	M 2.26	25.54
23	D 51.66	D 1.01	52.67	M 55.94	M 6.17	62.11	D 23.28	D 3.157	26.44
24	M 51.76	D 1.01	52.77	M 53.20	M 4.93	58.13	D 14.26	M 3.157	17.42
25	D 51.76	D 1.01	52.77	M 55.94	D 4.93	60.87	M 14.26	D 3.157	17.42
26	M 44.31	M .93	45.24	D 55.94	D 4.93	60.87	D 28.65	D 3.157	31.81
27	M 46.29	D .93	47.22	M 57.04	M 4.71	61.75	M 17.85	D 3.157	21.01
28	M 52.55	D .93	53.48	D 53.40	D 4.71	58.11	D 24.53	D 1.724	26.25
29	D 53.53	E .60	54.13	M 53.40	M 4.56	57.96	M 39.47	D 1.724	41.19
30	M 55.36	E .60	55.96	D 53.40	D 4.56	57.96	D 33.06	D 1.724	34.78
31	M 54.88	E .60	55.48				M 37.25	M 1.724	38.97
Total Sec. Ft..........	2153.53	89.75	2244.	1827.	130.	1957.	1055.	83.	1138.
Total Mill. Galls.......	1391.	57.98	1449.	1180.	84.	1264.	682.	54.	736.

M Meter gagings.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, TUOLUMNE RIVER, AT HETCH HETCHY CABIN ABOVE FALLS CREEK AND AT HETCH HETCHY DAM SITE AND OF FALLS CREEK.

1912.

		January			February			March	
Date	H. H. Cabin	Falls Creek	Total H. H. Dam site. Sum of Falls Creek and Cabin	H. H. Cabin	Falls Creek	Total H. H. Dam site. Sum of Falls Creek and Cabin	H. H. Cabin	Falls Creek	Total H. H. Dam site. Sum of Falls Creek and Cabin
1	E 90	D 1.72	91.72	M 113	M 30	143	93	68	161
2	E 90	M 2.50	92.59	M 116	M 32	148	98	57	155
3	E 90	D 2.59	92.59	M 108	M 32	140	88	24	112
4	E 90	D 2.50	92.59	E 110	D 32	142	104	33	137
5	E 90	D 2.50	92.59	M 111	D 32	143	164	42	206
6	E 90	M 2.33	92.33	M 124	M 39	163	314	65	379
7	E 90	D 2.33	92.33	M 107	M 33	140	231	50	281
8	E 90	D 2.33	92.33	M 106	M 29	135	220	45	265
9	E 90	M 2.68	92.68	M 110	M 31	141	189	49	238
10	E 90	D 3.39	93.39	M 118	M 25	143	183	41	224
11	E 90	M 4.10	94.10	M 109	D 26	135	169	37	206
12	E 90	D 4.10	94.10	M 108	M 21	129	172	35	207
13	E 90	D 4.10	94.10	M 101	M 25	126	170	37	207
14	E 90	D 4.93	94.93	M 108	M 26	134	153	43	196
15	E 90	D 4.93	94.93	M 109	M 24	133	190	38	228
16	M 94.93	M 6.17	101.10	M 105	M 24	129	184	37	221
17	M 78.41	D 6.17	84.58	M 109	M 27	136	177	41	218
18	D 73.63	D 6.97	80.60	M 129	M 37	166	186	38	224
19	M 70.86	D 6.97	77.83	M 133	M 36	169	249	48	297
20	D 70.86	M 15.71	86.57	M 116	M 26	142	274	45	319
21	M 74.66	D 15.65	90.31	M 113	M 26	139	E 251	E 46	297
22	D 76.53	M 15.11	91.64	M 89	M 20	109	196	47	243
23	M 74.62	D 15.11	89.73	M 109	M 19	128	223	46	269
24	M 70.15	D 15.11	85.26	M 81	M 18	99	294	58	352
25	D 70.15	M 12.70	82.85	M 71	D 18	89	294	70	364
26	M 110.84	D 15.56	126.40	M 86	M 18	104	278	64	342
27	M 108.60	M 18.42	127.02	M 81	M 14	95	242	51	293
28	D 118.73	D 19.16	137.89	M 77	M 14	91	290	72	362
29	M 118.73	M 19.90	138.63	M 84	M 19	103	367	81	448
30	D 112.10	D 21.62	133.72				290	21	311
31	M 112.10	M 23.35	135.45				251	26	277
Total Sec. Ft.	2786.	281.	3067.	3041	753	3794	6584	1455	8039
Total Mill. Galls.	1801.	182.	1983.	1964	487	2451	4253	940	5193

DAILY RUN-OFF IN CUBIC FEET PER SECOND, TUOLUMNE RIVER, AT HETCH HETCHY CABIN ABOVE FALLS CREEK AND AT HETCH HETCHY DAM SITE AND OF FALLS CREEK.

1912.

Date	H. H. Cabin	April. Falls Creek	Total H. H. Dam Site Sum of Falls Creek and Cabin	H. H. Cabin	May. Falls Creek	Total H. H. Dam Site Sum of Falls Creek and Cabin	June. H. H. Cabin	H. H. Dam Site
1	295	74	369	716	156	872	5473	6240
2	430	95	525	594	119	713	5690	6130
3	520	105	625	548	106	654	6885	7125
4	486	131	617	644	113	757	6321	7377
5	400	99	499	800	126	926	6890	5661
6	439	116	555	807	140	947	5324	6157
7	576	132	708	933	174	1107	5448	5765
8	582	144	726	1000	208	1208	4047	3910
9	617	151	768	1050	245	1295	3441	2809
10	508	126	634	1400	280	1680	3611	3017
11	433	103	536	1850	324	2174	3402	3425
12	437	99	536	1650	360	2010	3510	3219
13	366	92	458	2100	589	2689	3069	3360
14	374	87	461	2200	624	2824	2471	3602
15	419	90	509	2400	630	3030	2365	2847
16	534	93	627	2650	822	3472	2008	2585
17	433	100	533	3125	781	3906	2290	2472
18	509	101	610	3300	775	4075	2350	2767
19	382	85	467	3600	762	4362	2440	2875
20	331	71	402	2650	542	3192	2420	2962
21	304	62	366	2000	390	2390	1906	2262
22	297	58	355	1640	280	1920	1724	1656
23	305	60	365	1540	230	1770	1525	1250
24	400	91	491	1560	221	1781	1173	991
25	391	81	472	1775	228	2003	1027	1073
26	432	97	529	1455	258	1713	1233	1204
27	427	91	518	1650	342	1992	1252	1365
28	513	110	623	3550	520	4070	1298	1382
29	579	130	709	3775	700	4475	1240	1375
30	560	127	687	4075	715	4790	1084	1141
31				3950	725	4675		
Total Sec. Ft.	13279	3001	16280	60987	12485	73472	92917	98004
Total Mill. Galls.	8578	1939	10517	39398	8065	47463	60024	63311

LIST OF DISCHARGE MEASUREMENTS MADE ON ELEANOR CREEK BELOW LAKE ELEANOR IN 1901.

Date 1901.	Gauge Height (Feet)	Area of Section (Sq. Ft.)	Mean Velocity (Feet per Second)	Discharge (Sec. Ft.)
June 10	8.67	174.7	2.36	*411.4
June 22	9.77	282.6	2.80	793.26
July 8	8.51	185.4	1.68	310.1
July 16	7.91	168.36	1.56	263.12
July 18	7.80	164.2	1.37	225.15
July 27	7.45	154.	.94	144.76
Aug. 3	7.10	147.	.57	84.4
Aug. 10	6.92	137.3	.55	75.2
Aug. 17	6.48	13.79	2.19	† 30.22
Aug. 19	6.68	18.02	2.33	42.06
Aug. 23	6.47	14.21	2.22	† 31.52
Aug. 27	6.26	9.19	1.92	† 17.78
Aug. 30	6.05	8.53	1.62	† 13.85
Sept. 6	5.90	3.70	1.68	†622.
Sept. 14	5.70	2.60	1.57	† 4.08
Sept. 21	5.72	2.65	1.90	† 5.02
Sept. 26	5.85	3.66	1.60	† 6.77
Oct. 3	6.40	13.14	2.62	† 34.48
Oct. 10	6.21	10.08	2.10	† 21.14
Oct. 14	6.12	8.10	1.85	† 15.

* About below the lake.

† At foot bridge 1000 above previous observations.

RATING TABLE FOR ELEANOR CREEK BELOW LAKE ELEANOR—1901.

Based on the Results of Gaugings Made in 1901, the Following Table Was Prepared From Which the Flow of Eleanor Creek May Be Approximated When the Stage of Water Is Known:

Height on Gauge	Discharge (Sec. Ft.)	Height on Gauge	Discharge (Sec. Ft.)
5 feet	..	8 feet	232
5.5 "	3	9 "	510
6 "	11	10 "	970
7 "	78	11 "	1770

The gauging station is located at foot bridge below Lake Eleanor.

NOTE: The above data are from page 44, "Reports on the Water Supplies of San Francisco, 1900 to 1908, inc.", published by authority of the Board of Supervisors, 1908.

The data are the bases of the estimates for June, July, August, September and October, 1901.

Lake Eleanor Notes.

For gagings of 1910 and 1911, watershed area above gaging station 77.8 sq. miles.

Records in brackets in 1910 record, are from discharge curve.

In 1911 and 1912, record D denotes estimated from discharge curve; M denotes actual meter gaging taken.

In 1912, all of the Eleanor Creek records, January to June, are estimated from discharge curve.

Note: The ratings on which the measurements for Lake Eleanor in 1901 are based, are from page 44 of "Reports on the Water Supplies of San Francisco, 1900 to 1908, inclusive."

These ratings are also found in U. S. Water Supply Paper No. 81, page 384-5, and in U. S. Water Supply Paper No. 66, page 147.

"A gaging station was established at the outlet of Lake Eleanor, June 1, 1901, by J. B. Lippincott, for the City of San Francisco."

ESTIMATED DAILY RUN-OFF IN CUBIC FEET PER SECOND, ELEANOR CREEK, BELOW LAKE ELEANOR.

Watershed Area Above Dam Site 79.2 Square Miles. Discharge Measurements Based on Actual Measurements.

Date.	June.	July.	Aug.	Sept.	Oct.
1	*1770	510	*122	*18	*23
2	1834	510	*105	*15	*28
3	*1370	510	91	*15	28
4	1130	510	* 91	*11	*28
5	*1050	*350	* 91	*11	*23
6	970	350	* 78	8	*23
7	* 650	*350	* 78	* 8	*23
8	* 480	367	* 65	* 8	*20
9	501	374	* 65	* 8	*18
10	392	*374	75	* 8	18
11	* 374	*374	* 65	* 8	*18
12	* 374	*374	* 56	* 8	*18
13	374	227	* 47	* 5	*17
14	970	227	* 40	5	15
15	970	227	* 34	* 5	*15
16	970	231	* 34	* 5	
17	970	215	34	* 5	
18	970	208	* 40	* 5	
19	970	218	* 47	* 5	
20	810	*218	* 40	* 5	
21	* 810	*218	* 40	5	
22	791	190	* 34	* 6	
23	* 747	*190	34	* 6	
24	747	*172	* 28	* 6	
25	* 747	*172	* 28	* 6	
26	* 747	*155	* 23	7	
27	612	*146	23	* 8	
28	* 480	146	* 23	*11	
29	* 480	146	* 18	*15	
30	650	*138	* 18	*18	
31		*138	* 18		
Total Sec. Ft.	24710	8535	1586	254	315
Total Mill. Galls.	15963	5514	1024	164	203

* Indicates estimated gages.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, ELEANOR CREEK, ABOVE DAM SITE.

1910.

Date.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,349	230	252	401	579	559	89	14	1.	11	12	63
2	842	214	331	451	543	530	80	13	0.8	10	12	56
3	483	201	399	459	514	461	75	12	0.5	10	11	69
4	373	179	420	495	462	404	70	11	0.5	8	11	97
5	305	173	450	515	427	348	60	10	0.5	7	10	113
6	258	171	439	536	368	321	48	10	0.4	7	10	(114)
7	249	175	428	555	423	281	49	9	0.3	7	10	108
8	214	177	456	611	575	276	43	8	0	7	9	159
9	202	159	444	743	692	258	40	7	0	6	8	158
10	184	152	447	793	706	241	36	6	0	5	8	189
11	179	155	473	766	694	260	40	5	0	6	8	281
12	172	157	472	625	606	219	33	5	0	9	11	276
13	168	164	481	560	609	225	35	4	0	10	14	258
14	170	177	511	629	559	219	37	4	0	20	17	184
15	168	185	445	655	616	214	33	7	1	20	(19)	171
16	182	177	377	761	588	186	34	6	9	26	(21)	142
17	171	160	351	856	503	181	29	6	20	22	(24)	124
18	178	163	489	978	532	193	25	6	24	27	(27)	100
19	173	155	1,317	977	496	176	29	6	25	26	(30)	102
20	168	176	1,461	1,117	500	185	28	5	24	25	(33)	54
21	160	162	891	981	495	149	33	5	22	24	(38)	59
22	171	159	656	909	507	139	26	4	22	25	52	63
23	237	164	554	947	545	115	23	4	19	24	(54)	52
24	332	157	489	977	557	121	19	4	17	22	(56)	47
25	327	177	427	943	565	114	18	4	17	21	(60)	48
26	295	176	357	1,048	516	103	17	3	15	(19)	(64)	41
27	247	183	307	1,048	532	112	16	3	15	(18)	65	41
28	253	188	284	1,420	508	114	18	2	14	(17)	69	36
29	249		273	1,232	513	100	18	2	12	(16)	75	36
30	236		307	827	516	85	16	2	12	(15)	72	31
31	231		338		550		17	1		14		30
*	8,926	4,866	15,326	23,815	16,796	6889	1134	188	272	484	910	3302
**	5,766	3,144	9,901	15,385	10,850	4450	733	122	175	313	588	2133

1911.

Date	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1	M 29	M 1454	M 123	D 965	M 766	M 840	D 607	D 150	D 23	D 8	D 6	D 13
2	M 29	M 960	M 132	D 1036	M 706	D 965	M 628	D 138	D 21	D 8	D 6	D 13
3	D 27	M 654	M 146	D 1021	M 793	D 1150	M 667	D 127	D 19	D 8	D 6	D 13
4	D 25	M 517	M 234	M 895	M 849	M 1293	M 700	D 120	D 18	D 7	D 6	D 13
5	D 25	M 399	M 279	D 925	M 1235	M 1370	M 662	D 112	D 17	D 7	D 6	D 13
6	D 25	M 331	M 259	M 803	M 913	M 1346	M 669	D 105	D 15	D 7	D 5	D 13
7	D 22	M 288	M 255	M 698	M 741	M 1506	D 650	D 96	D 15	D 7	D 5	D 13
8	D 22	D 290	M 302	M 593	M 666	M 1384	M 626	D 90	D 15	D 7	D 5	D 13
9	D 23	M 264	M 297	M 721	M 814	D 1240	M 580	D 84	D 14	D 7	D 5	D 13
10	M 102	M 231	M 362	M 601	M 820	D 1330	M 496	D 80	D 14	D 7	D 6	D 13
11	M 124	M 246	M 310	M 500	M 842	M 1453	M 527	D 74	D 14	D 7	D 7	D 13
12	D 150	M 218	D 304	D 450	M 914	M 1724	M 473	D 71	D 13	D 7	D 10	D 13
13	D 155	D 230	M 295	M 375	M 866	M 1628	M 515	D 65	D 13	D 8	D 10	D 13
14	D 147	M 194	D 270	M 353	M 878	M 1498	M 594	D 63	D 13	D 7	D 10	D 12
15	D 166	M 218	M 252	M 342	M 709	M 1485	D 560	D 60	D 12	D 7	D 10	D 12
16	D 150	M 191	M 274	M 413	M 632	M 1573	M 600	D 56	D 12	D 7	D 12	D 12
17	D 144	M 178	M 277	M 461	M 509	M 1464	D 970	D 53	D 11	D 7	D 12	D 12
18	D 141	M 170	M 307	M 561	M 508	M 1376	M 759	D 48	D 11	D 7	D 12	D 12
19	D 137	M 183	M 330	M 724	M 686	M 1509	D 520	D 45	D 10	D 7	D 13	D 12
20	D 136	D 172	M 361	M 789	D 960	M 1358	D 440	D 42	D 10	D 7	D 13	D 12
21	D 221	D 166	M 388	M 744	M 985	M 1144	D 440	D 41	D 9	D 7	D 14	D 12
22	D 220	M 155	M 381	M 815	M 1280	M 1029	M 333	D 40	D 10	D 6	D 14	D 12
23	D 210	M 146	M 457	M 880	D 1475	D 1020	D 275	D 37	D 9	D 6	D 14	D 12
24	D 276	M 161	D 480	M 1022	M 1418	M 754	M 253	D 35	D 8	D 6	D 14	D 11
25	D 285	M 160	M 492	M 1038	D 1120	D 664	D 246	D 33	D 8	D 6	D 14	D 11
26	D 284	M 135	M 546	M 1069	M 831	M 696	D 233	D 31	D 8	D 6	D 14	D 11
27	D 236	M 157	M 569	M 1071	M 893	M 844	D 262	D 30	D 8	D 6	D 14	D 11
28	D 210	M 119	M 588	M 788	M 951	M 906	D 200	D 27	D 8	D 6	D 14	D 12
29	D 786		M 619	M 652	M 869	M 870	D 182	D 26	D 7	D 6	D 13	D 13
30	D 5000		M 690	M 609	M 864	M 797	D 172	D 25	D 8	D 6	D 13	D 13
31	D 3669		M 851		M 895		D 162	D 23		D 6		D 13
Total sec. ft.	13,174	8,587	11,430	21,914	27,388	36216	15001	2027	373	211	303	384
Total mil. gals.,	8510	5,547	7,384	14,156	17,693	23396	9691	1309	241	136	196	248

DAILY RUN-OFF IN CUBIC FEET PER SECOND, ELEANOR CREEK, ABOVE DAM SITE.

1912.

Date.	Jan.	Feb.	March.	April.	May.	June.
1	13	68	50	184	396	845
2	13	70	54	216	361	915
3	14	70	56	252	312	1059
4	14	70	63	291	322	1005
5	14	70	77	305	350	933
6	14	70	113	305	378	845
7	15	70	134	348	460	782
8	15	66	134	405	534	695
9	16	65	126	436	612	585
10	18	65	120	394	639	496
11	23	66	114	343	752	460
12	24	65	107	287	764	460
13	24	65	108	243	879	534
14	25	64	103	225	845	494
15	27	64	101	230	915	436
16	33	64	103	236	1005	389
17	37	64	101	247	951	361
18	40	77	100	247	1005	333
19	40	79	108	236	969	333
20	41	80	115	213	797	333
21	41	76	112	194	667	323
22	44	75	110	174	534	291
23	44	73	117	160	436	261
24	45	63	125	182	403	232
25	47	59	138	196	450	196
26	55	56	150	210	534	179
27	63	54	150	232	612	169
28	63	52	158	252	653	174
29	65	50	182	316	813	176
30	66		191	366	1023	172
31	67		182		829	
Total Sec. Ft	1060	1930	3602	7925	20200	14465
Total Mill. Galls	685	1247	2327	5119	13049	9344

LIST OF DISCHARGE MEASUREMENTS MADE ON CHERRY CREEK IN 1901 AT ELEANOR TRAIL CROSSING.

Date	Hydrographer	Meter Number	Gauge Height (Feet)	Area of Section (Sq. Ft.)	Mean Velocity (Feet per Second)	Discharge (Sec. Ft.)
July 8	C. A. Miller	138	11.40	414.7	2.20	*914.7
July 17	C. A. Miller	138	10.40	322.3	1.58	†509.5
Aug. 9	J. B. Lippincott	138	8.75	210.9	.53	†112.1
Aug. 19	W. W. Cockins, Jr	138	9.10	79.5	1.67	‡132.45
Aug. 20	W. W. Cockins, Jr	Floats	8.40	72.17	1.48	‡106.81
Aug. 24	W. W. Cockins, Jr	138	8.10	45.5	.94	‡ 43.01
Sept. 1	W. W. Cockins, Jr	138	7.80	23.25	.75	‡ 17.46
Sept. 7	W. W. Cockins, Jr	Floats	7.70	20.50	.31	‡ 6.14
Sept. 17	W. W. Cockins, Jr	55	7.00	3.35	1.28	†† 4.30
Sept. 22	W. W. Cockins, Jr	55	7.06	3.59	1.24	†† 4.45
Sept. 26	W. W. Cockins, Jr	55	9.05	79.50	1.75	§141.0
Oct. 2	W. W. Cockins, Jr	55	8.96	70.85	1.69	§119.93
Oct. 10	W. W. Cockins, Jr	55	8.00	39.00	1.10	§ 43.12

* Cherry River could not be gauged until cable was up.

‡ At ford, rain 40 hours at headwaters.

†† 50 ft. below ford.

† At cable.

§ At ford.

RATING TABLE FOR CHERRY CREEK, IN CHERRY VALLEY, AT ELEANOR TRAIL CROSSING.

Height on Gauge	Discharge (Sec. Ft.)	Height on Gauge	Discharge (Sec. Ft.)
7	4	11	750
7.5	8	12	1150
8	28	13	1550
9	129	14	1950
10	368		

See page 377 for additional notes about Cherry Creek gagings.

ESTIMATED DAILY RUN-OFF IN CUBIC FEET PER SECOND, CHERRY CREEK, ABOVE DAM SITE.

Watershed Area 115-6 Square Miles. Discharge Measurements Based on Actual Gaugings.

1901.

	May	June	July	Aug.	Sept.	Oct.
1		1270	1630	206	17	129
2		1390	1550	183	17	129
3		1490	*1310	162	17	129
4		1150	*1310	145	13	102
5		990	*1310	145	13	91
6		830	1310	129	13	60
7		*1150	1150	115	13	50
8		1430	910	102	13	50
9		*1150	* 910	102	13	34
10		1010	750	102	10	34
11		* 950	750	102	8	34
12		* 950	* 368	102	7	28
13		850	* 368	115	6	28
14		950	* 368	115	5	17
15		1030	368	115	4	23
16		*1030	368	115	4	
17		950	510	129	4	
18		750	* 510	129	4	
19		*1150	490	145	4	
20		*1150	460	60	4	
21		*1310	434	60	4	
22		1310	415	50	4	
23		*1270	384	41	8	
24		1250	365	34	28	
25		1350	338	34	70	
26	1230	*1350	322	34	145	
27	1230	1350	296	28	129	
28	1230	*1550	278	28	129	
29	1190	1750	255	23	129	
30	1230	*1950	242	23	129	
31	1270		218	17		
Total Sec. Ft.	7380	36060	20247	2890	964	938
Total Mill. Galls.	4767	23295	13080	1867	623	606

* Indicates estimated gage.

Cherry Creek Notes.

Daily meter gagings were made from February 9th to April 30th, 1911, and 18 gagings between June 23rd and July 15th, 1911.

The quantities were estimated from January 1st to August 29th, 1911, from rating curves based on above gagings.

From Aug. 30th to Nov. 1st, measts. were made over a 19-foot weir. Nov. 1st to Nov. 10th, over a 10-foot weir. Nov. 10th to Dec. 31st over a 19-foot weir.

Under direction of William Hammond Hall, for the Tuol. W. S. Co.

Tuolumne Water Supply Company. The quantities were originally computed, as the amount of discharge, between the hours of gagings. The discharge was computed in daily quantities, in the office of the City Engineer of San Francisco, by plotting the quantities given by Mr. Hall, and estimating the average flow from midnight to midnight. ( ) April 1st and 2nd estimated. The gagings for April are "Float gagings", and were generally taken once a day, though sometimes twice a day, 35 measurements were made in the 28-day period. The gagings for May are "Float gagings"; May 1st to 5th and May 31st measurements taken twice a day, balance of month once a day. June—"Float gagings", once a day except on June 30th, taken twice. July—"Float gagings", once a day except on July 31st, taken twice. August—"Float gagings"; August 1st weir measurements twice a day; August 2nd to 30th, inclusive, August 31st, three times. September—Weir measurements twice a day, September 1st to 13th, inclusive, no measurements on 14th, 15th to 30th float gagings. October—Float station, 1st to 5th, weir gagings 5th to 11th, no gagings on 12th, float station 13th to 21st, no gagings 21st to 26th, weir gagings 26th to 31st. November—Weir gagings, 1st to 6th, meter gagings twice daily 6th to 30th at bridge station. December—Meter gagings twice a day.

In January, 1912, a chronograph gage was installed at the Cherry Creek gaging station. In computing the daily discharge, the average of 12 heights (one every two hours) was taken from the chronograph charts and this average applied to a rating curve, the latter being compiled from actual meter gagings. Mr. O. J. Todd, hydrographer.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, CHERRY CREEK, NEAR DAM SITE.

Discharge Measurements Based on Actual Gagings. Watershed Area 115.6 Square Miles.

1910.

Date	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	(480)	640	1690	187	13	1	9	13	67
2	(480)	628	1560	173	12	1	9	12	54
3	480	710	1095	160	11	1	9	11	182
4	520	555	895	148	10	1	9	11	200
5	580	490	796	127	9	1	7	10	150
6	563	770	727	105	7	0	5	10	147
7	650	1060	663	100	6	0	5	10	260
8	810	1350	600	100	5	0	5	9	260
9	930	1615	617	100	5	0	4	8	220
10	820	1450	648	100	4	0	4	8	810
11	605	1327	717	98	4	0	12	20	610
12	645	1200	680	89	3	0	110	150	302
13	645	1305	597	78	3	20	202	105	165
14	720	1380	572	65	3	350	182	98	120
15	730	1538	495	57	2	795	170	95	105
16	855	1345	481	53	2	860	159	71	90
17	1025	1050	480	50	2	270	146	67	79
18	1200	1030	475	57	2	137	120	93	81
19	1300	1100	465	87	2	90	93	102	60
20	1372	1214	408	77	1	61	74	95	45
21	1290	1255	355	65	1	47	58	102	35
22	1377	1427	297	55	1	30	50	95	35
23	1415	1427	266	47	1	27	43	113	38
24	1552	1774	258	40	1	24	37	152	48
25	1645	1600	260	33	1	18	30	147	45
26	1933	1385	272	28	1	14	24	128	38
27	1970	1385	285	22	1	12	21	102	39
28	2500	1505	271	16	1	11	18	88	35
29	1080	1400	232	14	1	11	16	80	35
30	780	1480	203	14	1	10	15	85	35
31		1720		13	1		15		27
Total Sec. Ft.	31012	38115	17360	2358	117	2792	1661	2090	4417
Total Mill. Galls.	20034	24622	11215	1523	76	1804	1073	1350	2853

DAILY RUN-OFF IN CUBIC FEET PER SECOND, CHERRY CREEK, AT RESERVOIR SITE ABOUT 8000 FEET ABOVE DAM SITE.

Watershed Area Above Gage Section About 114.3 Square Miles.

1911.

Date.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec
1	27	1560	150	1065	900	1125	1735	320	45.	9.	4.3	11.5
2	27	1260	151	1125	870	1650	2000	280	42.	14.5	3.9	11.2
3	27	980	275	1075	1060	2000	2160	245	38.	10.4	3.8	10.5
4	27	700	330	882	1450	2450	2080	222	36.	9.5	3.4	11.5
5	27	450	200	906	1575	2675	2080	210	32.	17.	3.2	16.2
6	27	382	183	746	947	2500	2100	190	29.	11.	3.1	16.0
7	27	370	184	637	860	2475	2050	174	26.	9.5	3.	27.2
8	27	323	265	610	940	2225	1800	167	22.	8.6	2.8	20.
9	37	316	322	722	1000	2275	1670	152	20.	10.5	2.5	16.8
10	146	280	345	510	970	2700	1730	143	17.	20.3	49.	12.7
11	156	248	257	428	1200	3100	1870	135	16.	13.	29.	11.
12	90	240	234	365	1245	3275	1820	126	14.	10.	30.	9.9
13	96	256	235	330	1097	3225	1910	114	13.	9.2	31.7	8.0
14	140	221	248	315	1020	3000	1860	105	12.6	8.8	25.5	7.5
15	290	214	245	365	765	3150	1830	105	11.4	8.4	32.7	7.3
16	218	207	300	460	634	3275	1800	94	11.	8.	37.	6.7
17	165	198	332	544	569	3200	1725	87	10.	8.	38.	8.2
18	145	194	350	733	698	3225	1725	82	9.4	7.2	35.5	11.4
19	173	190	385	832	1180	3350	1450	78	9.4	6.6	38.	12.5
20	330	172	404	824	1440	3425	1150	75	8.8	6.	36.2	11.4
21	295	169	399	820	1680	2900	880	68	8.	6.	32.	8.4
22	181	172	450	935	2040	2875	750	63	7.4	5.6	24.5	8.
23	192	172	495	1100	2240	2100	685	58	7.4	5.2	19.2	9.
24	430	162	493	1320	2010	1500	630	53	7.	4.8	18.	8.3
25	310	159	535	1460	2005	1625	616	48	6.6	4.8	17.8	7.4
26	173	151	548	1460	1190	2250	535	47	10.	4.4	17.5	6.3
27	142	150	550	1020	1315	2775	500	45	8.	4.8	16.5	6.7
28	250	150	595	710	1440	2550	458	43	7.4	5.4	15.1	6.7
29	2300		700	648	1420	2250	438	43	7.	5.2	12.6	7.5
30	7000		834	763	1150	1900	395	48	6.6	4.8	11.8	8.7
31	2850		1005		1210		353	46		4.4		10.2
Total Sec. Ft.	16325	10046	11999	23710	38120	77025	42785	3666	498.	260.9	597.6	334.7
Total Mill. Galls.	10546	6490	7751	15317	24626	49758	27639	2368	322.	169.	386.	216.

DAILY RUN-OFF IN CUBIC FEET PER SECOND, CHERRY CREEK GAGING STATION, ABOUT 8000 FEET UPSTREAM FROM DAM SITE.

Watershed Above Gage Station About 114.3 Square Miles.

1912.

Date.	Jan.	Feb.	March.	April.	May.	June.
1	13	70	59	194	410	2000
2	16	70	55	330	288	2245
3	18	71	53	360	259	1825
4	22	71	76	278	316	1927
5	24	72	150	278	372	2091
6	28	72	218	330	412	1927
7	33	71	150	425	597	1772
8	40	69	93	425	700	1670
9	45	68	87	408	827	1566
10	53	67	82	330	963	1411
11	49	65	76	303	1090	1411
12	46	62	71	233	1250	1435
13	47	61	71	202	1412	1462
14	49	60	71	244	1515	1309
15	51	59	71	278	2005	1125
16	52	58	73	244	2205	903
17	53	63	75	197	2040	850
18	54	67	82	168	1900	925
19	54	80	93	140	1660	1007
20	54	67	100	117	1257	1040
21	54	58	93	140	848	894
22	54	56	82	157	592	628
23	53	54	87	175	522	408
24	52	42	137	230	616	316
25	50	27	135	194	1100	290
26	55	32	134	244	1180	372
27	62	37	133	213	1257	459
28	64	49	133	255	1359	475
29	66	63	140	278	1462	455
30	68		157	330	1566	413
31	70		175		1670	
Total second feet	1449	1761	3212	7700	33650	34611
Total million gallons	936	1138	2075	4974	21738	22359

Appendix No. 20

CONCERNING THE PROPERTIES OF THE SPRING VALLEY WATER COMPANY, THE PRESENT SOURCE OF WATER SUPPLY FOR SAN FRANCISCO

Notes Compiled by J. H. Dockweiler, C. E.

The City of San Francisco is located on a peninsula surrounded on the west, north, and east by the waters of the Pacific Ocean and San Francisco Bay. It occupies roughly an area 7 miles square, and contains a land area of 46.5 square miles.

The topography is broken by a series of hills rising from sea level to an elevation of over 800 feet. About 60 per cent of its area is now thickly built up and during 1911 was supplied by the Spring Valley Water Company with an average of 37½ million gallons of water daily, which is the present capacity of its system.

Source of San Francisco Water Supply

Apart from a small local water plant now owned by the City of San Francisco, which plant is situated in the southeast corner of the city and was installed by a local land company to sell its lots, the Spring Valley Water Company furnishes all the water sent into San Francisco. The per capita consumption is 100 gallons daily; 85 from Spring Valley and 15 from wells, which latter are private sources of supply.

Excessive Storage Required for Water Supply in the Bay Region

It is to be remembered that conditions covering water supply in the San Francisco Bay region of California are different from those which confront most cities in the East. In this California region practically all water supplies of magnitude must be conserved artificially by the construction of storage reservoirs, which impound the waters from intermittent and flashy streams during periods of flood in the short five months season of rainfall. The variability of rainfall during seasons, and the cycles of seasons has made imperative the rule, based upon experience, that 900 days' supply must be carried in storage or impounding reservoirs.

Source of Water Supply Used by the Spring Valley Water Company

The Spring Valley Water Company obtains its present supply of water from two sources: the Peninsula System and the Alameda Creek System.

The Peninsula System comprises 5 storage or impounding reservoirs located on the peninsula—one, Lake Merced, in the City of San Francisco, and the other 4 south of San Francisco. These reservoirs have a combined storage capacity of 33 billion gallons, and in 1911 four of them supplied an average of 22 million gallons daily to San Francisco—the fifth one, the Portola reservoir, is not in use in supplying the City of San Francisco, its storage capacity being only 330 million gallons.

The Alameda Creek System, located in the East Bay Region, consists of a development of an average of 15.5 million gallons daily by diversion of the waters of Alameda Creek at the Sunol Filter Galleries. The present development of the Alameda Creek System includes no storage reservoirs.

Delivery Conduits from Sources to City Reservoirs

The Peninsula supply is delivered by gravity into the main city distributing reservoirs, with the exception of 3 million gallons daily from Lake Merced, elevation 19 feet above mean sea level, which has to be pumped.

The Alameda Creek supply is delivered by gravity from the Sunol Filter Galleries through a single pipe subdivided into four submarine pipes where crossing the Bay of San Francisco at Dumbarton Point to the Belmont Pumps located on the peninsula about 26 miles south of the city. From this point it is forced into the University Mound Distributing Reservoir.

The total length of main pipe conduits (30 to 54 inches in diameter) leading into the City distributing reservoirs from the sources of supply is 74.3 miles. Included in this are two sets of submarine pipes 16 and 22 inches in diameter.

Only two main pipe conduits deliver water into the City distributing reservoirs.

The supply from the Pilarcitos Reservoir is combined with that from San Andreas and is delivered by one pipe line into the middle and high services at College Hill Reservoir and Lake Honda respectively. The Crystal Springs and Alameda Creek water is combined and delivered by a single 44-inch pipe into the low service at University Mound Reservoir.

City Distributing Reservoirs

The main residence section being located upon a series of hills, the water supply must necessarily be delivered at different elevations to properly serve the various districts, and for this reason the city distributing system is divided into four supply zones or levels, namely: the low, middle, high and hill service areas.

There are nine City distributing reservoirs at elevations ranging from 135 feet above mean sea level to 600 feet with a total storage capacity of 90 million gallons.

Three of the City distributing reservoirs receive their water directly from the sources of supply:

University Mound, the Low Service supply, at elevation 165 feet;

College Hill, the Middle Service supply, at elevation 255 feet;

Lake Honda, the High Service supply, at elevation 360 feet.

From these three reservoirs the water is passed into the City pipe system where a portion is distributed directly and that portion required for higher levels is pumped from the city mains into reservoirs which are suitably located to supply these high districts.

Pumping Plants

The system includes eight pumping plants; three are connected directly with the City distributing system, of which one, the Precita Valley, is an emergency pump; and five are located between the sources of supply and the City distributing reservoirs.

Of the latter five pumping plants, two, the Belmont and Milbrae (the latter an emergency pump) are connected with the Alameda Creek source. The other three, Lake Merced, Ocean View and Central (the last now under construction) are located within the City limits and pump from the storage reservoir supply into Lake Honda, which is the High Service distributing reservoir.

The largest of the pumping plants is the Belmont with a capacity of 23 million gallons daily, but only averaging 15.5 million gallons daily, which it pumps into the University Mound reservoir. The other pumping plants have a capacity ranging from 2.5 million gallons daily to 8 million gallons daily. All of the pumping plants pumped an average of 32.8 million gallons daily during 1911, against heads averaging from 110 to 172 pounds per square inch, or from 254 to 396 feet.

City Distributing System

The City distributing system on July 1st, 1912, contained 453.4 miles of pipe. Of this, 98 miles was 4 inches in diameter and under, and 356 miles was over 4 inches in diameter. In material, 442.2 miles was of cast iron and 11.2 miles of wrought iron.

The total number of service connections, or taps, on Jan. 1st, 1912, was 59,445, or about one tap for 8 persons. The total number of meters was 14,895, or 25 per cent of the total number of taps.

Quantity of Water Delivered in 1911

The average quantity of water delivered daily for the year 1911 was 37.5 million gallons, distributed as follows:

14.8 M. G. D., or 39.5%, to the Low Service area,
5.3 M. G. D., or 14.1%, to the Middle Service area,
17.4 M. G. D., or 46.4%, to the High and Hill Service areas.

Lands, Water Rights and Rights of Way Including Those Not at Present in Use

The Spring Valley Water Company owns 102,681 acres of land in fee simple, situated in six counties of the State of California, riparian water rights of 53,232 acres located in three counties, in addition to those whose fee it owns, and 68 miles of right of way in three counties.

It has bought lands and water rights which it either considered available to itself or purchased to prevent competition with its monopoly of the water supply of San Francisco. It succeeded the Spring Valley Water Works which had secured the property of the following companies:

Sausalito Water and Steam Tug Company.
San Francisco City Water Works.
Mountain Lake Water Company.
Islais and Salinas Water Company.
Alameda Water Company.
The Washington and Murray Township Water Company
Lake Merced Water Company.
Clear Lake Water Company.
San Mateo Water Works—lands and water rights except 300,000 gallons of water daily.
Manzanita Water Company.

The Sausalito Water and Steam Tug Company owned a few lots in the town of Sausalito, some boats, etc., with which it supplied water to shipping, etc., in San Francisco. On Sept. 12, 1861, the company sold out to the San Francisco City Water Works, and agreed not to furnish any water to any shipping or forts in the harbor of San Francisco.

The Mountain Lake Water Company owned a franchise and was reputed to own some rights and properties in Mountain Lake.

The Islais and Salinas Water Company owned water rights and properties on Islais Creek in the City of San Francisco.

The San Francisco City Water Works was an active competitor in the City of San Francisco, supplying water from Lobos Creek.

The Alameda Water Company owned the Vallejo Mill and water rights—one of the oldest appropriated water rights in the State of California—lands in the Calaveras reservoir site, and water rights. The City of San Francisco was negotiating for this property at the time of its purchase by the Spring Valley Water Works.

The Lake Merced Water Company and Clear Lake Water Company owned water rights, etc., in Lake Merced.

The San Mateo Water Works owned lands in the present Crystal Springs reservoir, and water rights.

The Manzanita Water Company owned lands in the Searsville reservoir and properties and water rights on San Francisquito Creek. The Spring Valley Water Works built a dam 50 feet high—creating the Searsville Reservoir. It is proposed to raise it 50 feet higher. All water below the level of the 50-ft dam belongs to the Manzanita Company—above to the Spring Valley Water Company.

The Washington and Murray Township Water Company owned an irrigation ditch which supplied water to lands in the vicinity of Niles—taken from Alameda Creek.

Clear Lake in the northern part of the State was suggested as a source of water supply. The Spring Valley Water Works by means of the California Agricultural and Improvement Company held lands on the margin of this lake.

The Clear Lake Water Company also owned some property in that vicinity, as the records show that the Spring Valley Water Company through one of its officers paid its bills.

Following are the lands in fee, the water rights and the rights of way owned in 6 counties by the Spring Valley Water Company, including the lands and rights not at present in use.

	Owned in fee acres	Riparian rights to acres	Rights of way lin. feet
San Francisco	2,177.62		22,750
San Mateo	31,869.53	24,512	167,336
Santa Clara	31,289.08	20,560	
Alameda	36,654.03	8,160	169,933
San Benito	690.97		
Marin	0.23		
Totals	102,681.46	53,232	360,019

Income and Expenses

The total income of the Spring Valley Water Company during the year 1911 from all sources including rents and outside sales was $2,993,336.33,—of which $2,891,337.38 was from sales of water in San Francisco,—which amounts to 21.9 cents per 1000 gallons for the quantity delivered in San Francisco.

The total expenses for operation, taxes, depreciation, and obsolescence was $1,317,187.46, which amounts to 9.6 cents per 1000 gallons.

Capitalization

The Spring Valley Water Works was incorporated on the 19th day of June, 1858, with a capital stock of Sixty Thousand Dollars ($60,000.00). This amount was increased on the 16th day of June, 1860, to the sum of Three Million Dollars ($3,000,000.00); in 1865, on the 9th day of February, the Capital Stock was further increased to Six Million Dollars ($6,000,000.00); and on March 20th, 1868, it was again increased to the sum of Eight Million Dollars ($8,000,000.00), being still further increased on July 6th, 1876, to the amount of Sixteen Million Dollars ($16,000,000.00), of which only Fourteen Millions was issued, which sum was the capital stock at the time said Spring Valley Water Works transferred its properties and rights to its successor in interest, the Spring Valley Water Company, which was incorporated under the laws of the State, on the 14th day of September, 1903, with a capital stock of Twenty-eight Million Dollars ($28,000,000.00). No new money was put in to make up this Twenty-eight Million Dollars, the stockholders were simply given two shares in the new company for one in the old.

HISTORY OF THE DEVELOPMENT OF THE WATER SUPPLY OF THE CITY OF SAN FRANCISCO.

Early Water Supply

Previous to 1851, all the water used in San Francisco was secured from small springs and wells inside the city, and from springs across the Bay, at Sausalito, in Marin County, the latter supply being brought to the city by boat. The distribution was made by means of wagons or carts, the water being sold by the bucket and barrel.

Mountain Lake Water Company

The first steps toward introducing a water supply into the City of San Francisco were taken on June 1st, 1851, when the Board of Aldermen passed an ordinance granting A. D. Merrifield et al a franchise, and on August 14th, 1851 Merrifield and his associates incorporated the Mountain Lake Water Company for this purpose. The source of supply selected was Mountain Lake, covering about 7 acres and located at the head of Lobos Creek, situated in the southwestern portion of the present United States Military Reservation at the Presidio, San Francisco. The Company proposed to build a gravity conduit from the Lake down Lobos Creek and thence along the water front, to a proposed reservoir at North Beach. Owing to injudicious expenditures in construction, (an expensive brick aqueduct having been planned) the company's funds gave out and it was unable to complete the work within the time allowed by its charter. From time to time, several other acts and ordinances were passed for its relief, but without avail.

San Francisco City Water Works

While the Mountain Lake Water Company was struggling with its financial difficulties, the San Francisco City Water Works was incorporated on June 15th, 1857, under the general laws of the State, for the purpose of supplying San Francisco with water. The projectors of this company also selected Lobos Creek as its source of supply, which water they proposed to divert at a point near the ocean and high enough to allow it to flow by gravity through a redwood flume, to be built along the ocean and bay shore, to a pumping station to be located at the shore of the Bay and Van Ness Avenue. The Board of Supervisors of San Francisco granted the San Francisco Water Works a franchise on August 6th, 1857. The proposed redwood flume and conduit were built by the company, and on September 16th, 1858, water was delivered into the city. A pumping station forced the water into two reservoirs, one located on top of the hill at the corner of Hyde and Lombard streets, the other on the bay shore slope of the same hill at a lower elevation, at the corner of Hyde and Francisco streets, from which the water flowed by gravity into the distribution system. These two reservoirs are still in use.

The Mountain Lake Water Company fought the San Francisco City Water Works in the courts, but was unsuccessful, and finally, about 1862, practically ceased to exist. Its properties and franchises were subsequently acquired by the Spring Valley Water Works.

Spring Valley Water Works

In the earlier part of the year 1858, one George H. Ensign obtained the rights to a small surface spring situated on Mason street near Washington, and on April 23rd, of the same year, secured a franchise to lay down pipes in the streets and to supply water to the citizens; on account of the insignificant supply of water from this spring, the usual reservations of free water for municipal supply were without difficulty overcome and excluded from the franchise, with the exception of free supply for the extinguishment of fires.

Within sixty days, Ensign proceeded to incorporate under the laws of the State, and on June 19th incorporated with a capital stock of $60,000, the Spring Valley Water Works.

After this company was duly incorporated, Ensign did nothing further toward the development of the water supply except to negotiate for some three inch pipe, thus complying with Section 1 of the Ensign Act, but never either bought or laid it down; with this exception and that of taking steps to obtain relief from the legislature to prevent forfeiture of his franchise when about due to expire, the company lay dormant until in the year 1860, when A. W. Von Schmidt, leaving the San Francisco City Water Works, and associating himself with several capitalists, purchased Ensign's expiring franchise, and the franchise and property of the Islais and Salinas Water Company, which owned 20 acres and water rights on Islais Creek, and took steps as the Spring Valley Water Works to bring water into the city.

Islais Creek

Islais Creek, in the City of San Francisco, and Pilarcitos Creek, in San Mateo County, were decided upon as sources of supply. The first water brought into the City of San Francisco by the Spring Valley Water Works was from Islais Creek, in the year 1861, by means of a flume about 3½ miles long leading out from said creek at a point about ½ mile above the Mission Road.

Pilarcitos Reservoir

Then a small dam 35 feet high was built in the Pilarcitos Valley, about 17 miles south of San Francisco, giving a storage capacity of about 60 million gallons, from which water was supplied to the city, by a conduit about 32 miles long, by way of the Lake Honda distributing reservoir, about the year 1862. This dam was added to from time to time until, in 1864, when this supply was found insufficient to meet the constantly increasing demand, it was decided to build a larger dam at a point further down the valley. This work was commenced in the same year and the dam was built to a height of 90 feet, thereby making a reservoir of a storage capacity of about 1000 million gallons at high water mark, 696 feet above sea. This is the present Pilarcitos Reservoir, now in use.

Lobos Creek

Lobos Creek, a small stream running westerly from Mountain Lake, was secured by the company in 1865 through purchase of the San Francisco City Water Works, and was used as a source of supply to the extent of about 2 million gallons a day, until the year 1903 when, the water being considered unfit for domestic purposes by the health department on account of the growing population in its watershed, its use was discontinued.

Lombard Street Reservoir

The first distributing reservoirs to be built in San Francisco were those of the San Francisco City Water Works, the Upper Russian Hill or Lombard Street Reservoir, and the Lower Russian Hill or Francisco Street Reservoir, which became the property of the Spring Valley Water Works by the purchase of the said San Francisco City Water Works in 1865. The Upper Russian Hill or Lombard Street Reservoir, at an elevation of 305 feet and with a capacity of about 2.5 million gallons, is located on the summit of Russian Hill, west of Hyde Street between Greenwich and Lombard Streets, and was built about the year 1860.

Francisco Street Reservoir

The Lower Russian Hill or Francisco Street Reservoir, built about the same time as the Upper Russian Hill, is located on the northern slope of Russian Hill between Chestnut and Francisco Streets, at an elevation of 135 feet and with a capacity of 4 million gallons.

The Upper Russian Hill or Lombard Street Reservoir has, since its acquisition by the company, been connected with the Lake Honda distributing system, while the Lower Russian Hill or Francisco Street Reservoir has been placed on the University Mound distributing system. The Black Point pumping station at the edge of the Bay at Van Ness Avenue, is supplied from University Mound and Francisco Street Reservoirs.

Laguna Honda Reservoir

Previous to the acquisition of the San Francisco City Water Works by the Spring Valley Water Works, the latter company had built, in 1861 and 1862, the Laguna Honda Reservoir, near the Alms House, the Market or Buchanan Street Reservoir, and the Brannan Street Reservoir, near 16th Street. Water was conducted from Pilarcitos Creek by gravitation through about 32 miles of flume, tunnel and pipe, to the Lake Honda Reservoir, elevation 360 feet above sea, at the rate of about 2 or 2½ million gallons daily. From here the water was conducted into the Market or Buchanan Street Reservoir, elevation of about 200 feet, with a capacity of about 2 million gallons, from which pipes led for the supply of consumers, and to the Brannan Street Reservoir, but this latter reservoir being at but an elevation of about 100 feet, was abandoned in about the year 1864 or 1865, as being entirely too low for a satisfactory distributing point, and the company used but the Market or Buchanan Street Reservoir, from which a much better pressure could be obtained. In 1893 the city began the cutting through of Ridley Street, which practically ran through the center of the Market or Buchanan Street Reservoir property, thereby throwing this reservoir out of service.

In 1865 or thereabouts, the Laguna Honda was emptied for the purpose of reconstruction; it was excavated and remodeled to form a large distributing reservoir with a storage capacity of 33 million gallons.

San Andreas Reservoir

In 1867 the Spring Valley Water Works commenced the construction of the San Andreas dam, about two miles southwest of Milbrae Station and two miles northeast of the Pilarcitos Reservoir. This was completed to a height of 82 feet in about 1869 and in 1871 or 1872 was further raised to a height of 90 feet, with a capacity of 6,100 million gallons, at high water mark, 446 feet above sea.

College Hill Reservoir

In the year 1870 the College Hill Reservoir, which was built to receive the waters from the San Andreas system, was put into service. This reservoir is located on a spur of Bernal Heights, near and to the west of Holly Park, and is at an elevation of 255 feet above sea. It has a storage capacity of 14 million gallons and supplies, in general, a narrow strip west of Valencia Street, north of Market Street and as far east as Kearny Street, being principally between the 40 foot and the 200 foot level.

Locks Creek Line

In May of 1870 began the construction of Locks Creek Tunnel No. 1, which was completed in May of 1873, being a portion of the so-called Locks Creek Line, which was contemplated for the purpose of carrying into the San Andreas Reservoir a portion of the waters of the watershed of Locks Creek, which flows into the Pacific Ocean. The original Locks Creek Line or flume was begun in June of 1871, and completed in May of 1875, being nearly 20 miles in length. Later on, in November of 1897, the new Locks Creek line was begun, being completed in June, 1899. In the meantime, the upper portion of the original Locks Creek Aqueduct, consisting of flumes and pipes above Aponolio Creek crossing, being in bad condition and in need of repairs, had gone out of service and to the present time has not been put in condition for further use.

Alameda Creek Land and Water Rights

In the year 1875, after Engineer T. R. Scowden, at that time employed by the City of San Francisco upon the water supply investigation, had recommended, on April 19th, that the city derive its own water supply from the Calaveras Valley, the Spring Valley Water Company forestalled such a proposition by purchasing, for $1,000,000, in June of said year, about 2300 acres of land in the Calaveras Valley, which included part of the reservoir site situated about eight miles south of Sunol Station; also the Vallejo Mills properties, near Niles, where a dam and an old stone aqueduct about two-thirds of a mile in length had been built some years previous. The above included water rights, etc. Subsequently the Washington and Murray Township Water Company was purchased, also extensive land holdings and water rights on Alameda, Laguna, San Antonio, Arroyo Valle and Calaveras Creeks, above Niles. Purchases were also made of water rights on both sides of Alameda Creek, also of lands in fee simple, from Niles to the Bay of San Francisco.

Crystal Springs Upper Dam

The Crystal Springs Upper Dam—an earthen dam— was begun in April of the year 1875, built to a height of 25 feet in 1878, and raised to a height of 75 feet in 1885, with a capacity of over 4 billion gallons.

44-Inch Crystal Springs Pipe Line

In 1886 the company laid a 44-inch line of pipe from Upper Crystal Springs Dam to San Francisco; previous to this time there having been made no direct connection to the City, the water had been used only to reinforce the supply from Pilarcitos Reservoir into whose pipe line this Upper Crystal Springs water had been pumped by a pumping station installed at the aforesaid upper dam. This pump station has long since been dismantled.

San Mateo Water Works

For the purpose of further enlarging the Crystal Springs system, the Spring Valley Water Works arranged to secure lands and properties further down the valley, with the intention of building a larger reservoir. On October 3, 1883, it purchased from the San Mateo Water Works its property, with the exception of its distributing reservoir and pipe in the town of San Mateo, and as a part of the consideration therefor the Spring Valley Water Works agreed to furnish said distributing reservoir of the San Mateo Water Works with 300,000 gallons of water per day.

Crystal Springs Reservoir

In 1887 the company commenced the Crystal Springs concrete dam, which it completed to a height of 115 feet in 1888. After a waste, in the winter of 1889-90, of over 6 million gallons of water, this dam was further raised to a height of 145 feet, thereby increasing the capacity of the Reservoir, including that of Upper Crystal Springs, to 19,000 million gallons. Flash boards have been placed on top of the concrete dam, bringing the high water mark of the reservoir up to 291 feet above sea, at which level the capacity of the Crystal Springs Reservoir is 23,000 million gallons. This necessitated raising the earth dam of the Upper Crystal Springs Reservoir over which the main county road passes to Halfmoon Bay. From the Crystal Springs reservoir the lower parts of the city east of Valencia Street, south of Market Street, east of Kearny Street and along the city front to North Beach and the Presidio, are furnished by way of the University Mound distributing reservoir.

Capacity of Three Peninsula Reservoirs

These three reservoirs, the Pilarcitos, San Andreas and Crystal Springs, have a total capacity of 30,100 million gallons, with an average daily safe yield of about 19 million gallons.

Lake Merced

Lake Merced, a body of fresh water situated partly in San Francisco County and partly in San Mateo County, with a surface area of about 350 acres, was divided into two bodies of water by artificially extending a narrow strip of land which ran part way across the lake, to the higher ground on the western shore, thus forming the so-called North and South Lakes, with a surface area of about 90 and 260 acres, respectively. The first acquisition of water rights on the Laguna de la Merced by the Spring Valley Water Works was in August, 1868, from the Lake Merced and Clear Lake Water Companies. And in 1877 it began the purchasing of lands about the lake and tributary thereto, until at the present date the Company owns about 2800 acres.

The water supply of Lake Merced is maintained by springs to the extent of about 3 million gallons per day, the surface run-off being prevented from flowing into the lakes by drainage systems which divert the same and carry it, with its impurities from the surrounding districts, into the ocean. The capacity of the Lake Merced Reservoir is 2500 million gallons at elevation 19 feet above sea level.

Lake Merced Pumping Plants

In 1877 and 1878 the company installed a pumping plant on the eastern shore of the North Lake, by means of which water was sent into the Pilarcitos pipe, but this plant has long since been dismantled and put out of service. In 1891 a new pumping plant was built on the northeast shore of the South Lake, with a pumping capacity of 7,500,000 gallons per day, 3,750,000 gallons from each of two Corliss engines. In the year 1900, water was being taken and used only from the South Lake, but since that time the North Lake has been protected from contamination, and in the year 1903 water was taken from it as well as the South Lake.

University Mound Reservoir

The University Mound Reservoir was constructed in 1880, at an elevation of 165 feet above tide, with 35 million gallons capacity. It receives its water through the Crystal Springs pipe line, from Alameda Creek and Crystal Springs Reservoir.

Lafayette Tank

The Lafayette tank, which was located on Lafayette Park Hill, on a line with Octavia Street, was removed in 1902 by order of the Park Commissioners. It was a rectangular wooden tank, of about 72,000 gallons capacity, built about the year 1884, at an elevation of 372 feet, being supplied by the Black Point pumps from the Crystal Springs system. This tank furnished water to the Presidio Heights and Pacific Heights districts, and after its removal, it was necessary to provide other means of supply.

Presidio Heights Tank

This was done by the construction of the Presidio Heights tank, which was begun in the latter part of the year 1902 and completed in the early part of 1903. It is located on the corner of Pacific Avenue and Lyon Street, at an elevation of 400 feet above sea, is built of steel, and has a capacity of 700,000 gallons.

Searsville Reservoir

About 1887 the company undertook the construction of a tunnel, 24,500 feet in length, from San Francisquito Creek to the Crystal Springs Reservoir, for the purpose of conveying to the said reservoir, and storing there, the waters of the San Francisquito Creek. This scheme, however, was later given up and it was proposed to build a dam at Searsville, to a height of 105 feet, and further, to build a pipe line to carry 5 million gallons of water daily to the Belmont pumping station and connect it there with the city main. The dam was built in 1891, to a height of 50 feet, giving a capacity of reservoir of 329.5 million gallons. When the dam is constructed to a height of 105 feet, as proposed, the reservoir capacity is claimed to be 3,300 million gallons, 300 million of which belong to the Manzanita Water Company, leaving about 5 million gallons per day available for the San Francisco supply. The present height of the dam, at 50 feet, being sufficient to satisfy the requirements of the Manzanita Water Company, the Searsville, or Portola reservoir has not been further developed, and has not been connected with the Spring Valley Water Company system.

Alameda Creek Pipe Line
Belmont Pump Station

In June of 1887—it being decided by the company that it would be cheaper to bring the waters of Alameda Creek under the Bay to Belmont, instead of further developing the Searsville Reservoir, and also that an additional supply of water would be required before the Lower Crystal Springs Reservoir could be utilized—the company began the construction of a pipe line designed to divert from the Vallejo Mills dam, also called the Niles Dam, the water of Alameda Creek, and bring it in to the Belmont pumping station, and thence by a pipe to a junction with the Crystal Springs pipe at Burlingame. This pipe line and pumping plant were completed and put in operation in August, 1888. The pipe is 36 inches in diameter, but reduced to two 16-inch pipes where it crosses the bay.

Sunol Gravel Beds

The diversion of water at this point on the Alameda Creek was continued until September of the year 1900, when the gravel beds of the Sunol Valley were thrown into use to filter the water received from Calaveras and Laguna Creeks. The new Sunol Dam, built across Alameda Creek at the lower edge of the Sunol gravel beds and the aqueduct were then completed, whereby the water entered the pipes at an elevation of 80 feet higher than at the original intake at Niles Dam, thus increasing the capacity so as to make it possible to deliver to the Belmont pumps about 10 million gallons per day. The diversion from the stone dam at Niles is practically out of use at the present date, except as it may be used in furnishing water to reparian owners.

Submarine Pipes

By the addition of two 22-inch pipes laid across the Bay from Dumbarton Point in 1902, the capacity of the Alameda pipe line was increased to about 17 million gallons per day, with a present daily delivery of about 16 million gallons. (There are four lines of pipe in the submerged portion crossing the bay, which here is about a mile wide—two of 16-inch, and two of 22-inch—but there is only a single line for the rest of the distance.)

Jones Street Tank

In, or about, the year 1890, the company built an iron tank west of Jones Street, between Washington and Clay Streets, at an elevation of 375 feet and with a capacity of 212,000 gallons. It received its water from the Crystal Springs system, through the Black Point pumps, and supplied the district about Clay Street Hill, generally bounded by the 200 foot level contour. Spring Valley Water Works reports and exhibits show a reservoir to have been built at this point as early as the year 1865, which is mentioned by Engineer T. R. Scowden as being at an elevation of 353 feet, and with a storage capacity of 140,000 gallons.

Clarendon Heights Tank and Pump Plant

The Clarendon Heights tank, located between Clarendon, Lincoln and Belgrave Avenue, at an elevation of 600 feet and having a capacity of 564,000 gallons, was built in 1895. It supplies the highest territory handled by the Spring Valley Water Company, water for this tank being furnished from the Crystal Springs system, through the 17th Street pumps, which were built this year, (1895).

Pilarcitos Pumps

In 1897 the Pilarcitos Pumps were erected at the outlet of the tunnel from San Andreas Reservoir. These pumps lifted the San Andreas water into the Pilarcitos pipe line which supplied Lake Honda.

In 1898 the Crystal Springs emergency pumping station, capacity 10 million gallons, and conduit to Lake San Andreas, were built. The pumps were located at the Crystal Springs concrete dam. They raised water from Crystal Springs Reservoir into San Andreas Reservoir.

Potrero Heights Reservoir

The Potrero Heights Reservoir, at an elevation of 315 feet, and with a capacity of 800,000 gallons, was built in 1897. It is supplied by the Lake Honda system and serves an independent district at the Potrero.

Laguna Creek and Pleasanton Wells

The first wells on Laguna Creek were sunk in 1898 and wells have been gradually added so that they now comprise over 100 in number not to exceed 40 of which are in use. The water is pumped from these wells into a pipe, which delivers it into the Sunol filter galleries, whilst formerly it flowed in an open ditch and discharged upon the Sunol gravels.

Millbrae Pumping Station

The Millbrae pumping station, capacity 16 million gallons daily, built at Millbrae station, was finished in April, 1899. Its function was to lift the water from the Crystal Springs Reservoir and Alameda Creek into the San Andreas pipe line, supplying the College Hill Reservoir.

New Alameda Pipe Line

A 54-inch pipe line, called the New Alameda Pipe line was connected at Burlingame with the 36-inch Alameda pipe, and from this point about 3 miles were laid during the year 1903, joining the Crystal Springs pipe line at Millbrae.

Since the earthquake of 1906, which destroyed the Pilarcitos pipe line between the San Andreas Reservoir and San Francisco, many changes have been made in the arrangement of the pumping stations, some being moved completely or partially, new ones installed. Branch pipe lines leading off from the main sources of supply pipes have been built. Before the earthquake, three pipe lines led into the city from the peninsula reservoirs; since that time there have been only two independent lines.

POSSIBLE SOURCES OF WATER SUPPLY AVAILABLE TO THE SPRING VALLEY WATER COMPANY FROM ITS HOLDINGS IN THE REGION OF SAN FRANCISCO BAY.

The sources of water supply considered available to the Spring Valley Water Company are: (a) four reservoirs storing the supply from the Peninsula watersheds, and Lake Merced; (b) the Alameda Creek watershed which supplies the Sunol and Pleasanton gravel beds, and will supply storage for three proposed reservoirs; (c) wells on the Peninsula near the southwestern end of the Bay of San Francisco; (d) water from the Coyote Creek watershed; (e) coast streams west and south of the Peninsula watersheds, which flow into the ocean. These sources of supply will be considered in order.

(a) Four Peninsula Reservoirs---Pilarcitos, San Andreas, Crystal Springs, Portola---and Lake Merced

The area of the watersheds supplying the Peninsula reservoirs and Lake Merced is 58.3 square miles. The present supply from the Peninsula reservoirs and Lake Merced is about 22 million gallons per day, which may be considered permanently available for use by San Francisco. This is the safe yielding capacity of the above reservoirs excluding Portola, which has not supplied any water to San Francisco, all of its water being used by Stanford University at Palo Alto. The Spring Valley Water Company owns about 29,000 acres of the 37,300 acres, which comprise the 58.3 square miles of watershed.

(b) Alameda Creek Watershed

The area of the Alameda Creek watershed is 623 square miles or about 400,000 acres, of which the Spring Valley Water Company owns about 48,000 or 12 per cent. It also owns water rights to 28,000 additional acres affected by Alameda Creek and its tributaries.

Million Gallons Daily

The average annual discharge from this watershed during the 8 year critical period beginning with the season 1897-8 was 61.6

If the three proposed storage reservoirs contemplated by the Spring Valley Water Company had been built, it is estimated that during this critical period of 8 years, the total supply of the whole Alameda Creek watershed would be 65.8

(50 M. G. D. of this from storage and 15.8 M. G. D. from the areas below the storage sites.)

The quantity of water absorbed by the gravels of the Niles Cone from Alameda Creek before water was diverted to San Francisco by the Spring Valley Water Company was 29.5

This leaves the average annual quantity of water available from the Alameda Creek watershed at. 36.3

The average quantity of water diverted to San Francisco from the Alameda Creek watershed during the year 1911 was 15.6

Subtracting this from 36.3 M. G. D., the average quantity available during the period leaves the probable quantity of water available for diversion to San Francisco in addition to the quantity diverted during 1911 at.... 20.7

This available quantity can be only temporary, because, when the maximum area irrigable in the Niles Cone—32,500 acres—is irrigated, there will be required for irrigation 56.7

This will require nearly the whole available supply of the Alameda Creek watershed—not considering the local requirements within the watershed itself, which will increase annually.

Effect of Diversion of Water From the Alameda Creek Watershed

Since the Niles Cone Region (population 11,000; area, about 74 square miles) is dependent upon Alameda Creek for its water supply, the seizure of this source of supply by outside communities, without providing a supply from other sources, cannot be justified. The water-table in the Niles Cone has already been lowered from 8 to 10 feet since the diversion by the Spring Valley Water Company of water for use in San Francisco.

Whereas formerly garden vegetables and crops could be raised without irrigation or with irrigation by ordinary suction pumps and windmills, it is now necessary for farmers to install expensive deep-well pumping plants to keep the crops and orchards alive. The future prosperity of the Niles Cone district depends entirely upon the conservation of its water supply from Alameda Creek.

No other supply is available for it. Notice has been served upon the Spring Valley Water Company and other water companies by land owners of the Niles Cone, protesting against any diversion of water from the Niles Cone. During the year 1911, about 8½ million gallons daily were pumped from this cone and used by communities not resident upon the cone—to-wit, Oakland, 8 million gallons daily, and Hayward ½ million gallons daily. Upon the cone itself, 5½ million gallons daily were used, or a total of 14 million gallons daily, all of which must come from Alameda Creek.

(c) Wells on the West Shore of the South End of San Francisco Bay

About the year 1905, the Spring Valley Water Company attempted to add to its supply by boring wells at Ravenswood on the west side of the south arm of the Bay of San Francisco. Some 40 wells were bored, but the water-table was so lowered through pumping that a water famine in Palo Alto, Stanford University, Mayfield, Menlo Park, Mountain View, and adjoining communities was threatened and, legal proceedings being proposed, operations were abandoned. The Spring Valley Water Company own about 8,500 acres in fee simple on the west shore of San Francisco Bay, in the vicinity of Alviso and Dumbarton. It also owns the riparian rights to many thousand acres adjoining the above 8,500 acres.

(d) Coyote Creek Watershed

The area of the Coyote Creek watershed is 231 square miles, and a water supply of about 50 million gallons daily may be developed from it. But when both the subterranean and surface waters are utilized the supply will even then be entirely inadequate for irrigation purposes in the Santa Clara Valley.

It is estimated that about 40,000 of the 100,000 acres of irrigable land in the Valley may be irrigated from the Coyote River flow when adequately reservoired, under the duty of water prevailing in the Santa Clara Valley.

Under court decisions, none of the waters of Coyote River, surface or sub-surface, may be utilized for the domestic supply of cities outside the confines of the Santa Clara Valley. The Spring Valley Water Company owns a tract of about 11,500 acres in the Coyote Creek watershed, which includes a large reservoir site.

(e) Coast Streams

The area of the watersheds of the coast streams which could be utilized for water supply is 64.7 square miles. From the experience with all other nearby sources, it must be assumed that the greater part of all the water flowing into the ocean from the coast streams west and south of the present peninsula watersheds will ultimately be required and demanded by the communities along the ocean shore, and therefore will not be available for use in San Francisco.

Studies made indicate that 37 M. G. D. could with sufficient reservoir and tunnel capacity be developed from these sources from watersheds tributary to points which will allow the above quantity to flow into the Crystal Springs Reservoir by means of tunnels leading through the crest of the ridge, but this estimate rests upon assumptions as to rate of run off in the creeks and not upon any long term continuous gagings during a typical flood period; obviously a flashy stream with very small reservoirs may present requirements in size for diversion tunnels that it may be financially impossible to meet. It will be assumed that 20 million gallons daily can be diverted temporarily from these streams for the use of San Francisco. The Spring Valley Water Company is reputed to own sufficient lands to control the reservoir and dam sites in these watersheds, in addition to riparian rights to many acres.

Summary of Conditions Affecting the Sources of Water Supply of the Spring Valley Water Company

If the rights of the communities of the Niles Cone should be determined as not being in excess of the 29½ million gallons daily which the gravels of the said cone absorbed before the Spring Valley Water Company diverted any water from Alameda Creek, the remaining quantity of water available to the Spring Valley Water Company during a dry period covering several consecutive seasons such as began with 1897-8, would amount to 36.3 million gallons daily.

The Searsville reservoir, if used by the Spring Valley Water Company, will doubtless be utilized for the purpose of storing water brought in from the coast streams by means of tunnels driven through the ridge, as it is considered that the product of the Searsville Reservoir watershed will be required for the communities dependent upon the San Francisquito Creek, upon which this reservoir is built.

The three peninsula reservoirs, Pilarcitos, San Andreas, and Crystal Springs, together with Lake Merced have an annual safe yield of 22 million gallons daily. Assuming that 20 million gallons daily might be available from the coast streams, with sufficient tunnel and storage capacity for conserving the sudden flows, the total available supply will amount to 78 million gallons daily, which is about double that used at present in San Francisco.

It is to be noted, however, that the Niles Cone is supplied from Alameda Creek, and when all of the lands capable of being irrigated are irrigated, practically all of the Alameda Creek water will be required on said cone, and for the use of the communities within the Alameda Creek watershed.

The communities residing on the west coast streams have no other source of water supply available than these same west coast streams. The Ocean Shore Railroad, which follows along the ocean shore through this region, will cause the rapid up-building of these communities, and will intensify the cultivation of garden truck, etc., now in its infancy. This will require a large quantity of irrigating water, hence it is fair to assume that the coast stream communities will need all of the water capable of being developed from said watersheds.

The communities lying to the east of and adjoining the Peninsula Reservoirs which are not now supplied from said reservoirs, if they are to grow, will require water from these sources. As has been shown no water from Coyote Creek is available outside of the Santa Clara Valley.

LITIGATION

Since the formation of the Spring Valley Water Works there have been three periods of litigation between it and the City. The litigation in the first period of about ten years, beginning with 1867, was on the question of whether the City was entitled to free water for municipal purposes, as stated in the franchise; in the second it was on the question of the method of fixing the rates to be charged for water, and began in the year 1877; and in the third, it was over the valuation of the properties of the company upon which should be based the reasonable rates to be charged. A separate suit being filed for each year since 1903 except the year 1906.

First Period of Litigation

Complying with the terms of their franchises both the Spring Valley Water Works and the San Francisco Water Works supplied the city with water free of charge up to the time of their consolidation and for two years following or until May, 1867, when a test suit was filed by the Spring Valley Water Company against the City to recover the sum of $1,728.48 for water used by the City in irrigating Portsmouth Square.

Then commenced a ten year struggle between the water company and the City, wherein the water company endeavored to compel the city to pay for all water used for municipal purposes with the sole exception of water actually used in the extinguishment of fires, basing its contention on a section of the Ensign franchise. This feature of the controversy was carried through the courts, being won by the company in the lower and by the City in the higher.

The company then endeavored to have the act granting the charter declared unconstitutional, which it succeeded in doing. It then renewed its demands that the city pay for the water consumed for municipal purposes. As the statute granting the charter had been declared unconstitutional, the city claimed that it was entitled to such water by virtue of the general incorporation laws under which it had been held that the company had received its charter. This contention was also carried through the courts and decided by the Supreme Court in favor of the city, thus finally ending the litigation, there being no further loophole left for the company, and it then, of necessity, withdrew its demands, now grown to nearly half a million dollars.

Upon the adoption of the New Constitution in 1880, the company became entitled to payment for all water used, at rates fixed by the Board of Supervisors.

Second Period of Litigation

The Spring Valley Water Works owned two special franchises granted by the State Legislature, "The Ensign Act" and the "Bensley Act." These special acts provided that water rates should be established by a commission. No record appears that any rates were ever so established, the water company having collected rates established by itself. In 1874 both of the above special franchises were declared unconstitutional.

In 1876 the legislature passed an act to establish water rates for the City and County of San Francisco, which, with its supplementary and amendatory acts, provided that the Mayor should appoint five commissioners to fix the rates. Such a board was appointed, and fixed certain rates, but the company refused to abide by the action of this board and on bringing the matter into court, succeeding in having the said act of the legislature declared unconstitutional.

Acting then in accordance with the general law, the Board of Supervisors, in 1877, appointed two members of a board of five to fix rates, of which the water company was to select two, with a fifth to be chosen by the first four. The company appointed its quota and this Board of Water Commissioners, in June, 1878, presented to the Board of Supervisors a schedule of rates to be instituted and remain in force and effect until new rates should be established.

The rates so established were in force until the year 1880, when the new constitution went into effect, and by virtue thereof the Board of Supervisors proceeded to establish water rates, fixing a schedule about 20% under that of the Board of Water Commissioners. The water company endeavored to revive the Board of Water Commissioners in order that it might enjoy the higher rates, and on the refusal of the Board of Supervisors to fill the vacancy then existing in the Water Commission, the company brought suit to compel such action. This suit, on being carried to the Supreme Court of the United States, was decided against the company.

Since that time all rates have been fixed by the Board of Supervisors.

Third Period of Litigation

The third period begins with the year 1901, when an action was brought to enjoin the water rates established by the Board of Supervisors for the fiscal year 1901-2. This action was dismissed by the Spring Valley Water Works on Dec. 31, 1902.

Beginning with the water rates established for the fiscal year 1903-4, and including rates established for the fiscal year, 1912-13, with the exception of the rates established for year 1906-7, suit has been brought each year to enjoin and set aside rates thus established.

The suits to enjoin the rates for the three fiscal years beginning with 1903-4 and ending with the year 1905-6 were decided by the U. S. District Court October, 1908; the court found that the ordinance did not allow the company 5% upon the value of the property used and useful in supplying water to the city of San Francisco and its inhabitants.

In these actions the water company contended that its property, used and useful for rate fixing purposes, had a minimum value of between 40 and 45 million dollars, with a maximum of 70 million dollars. The City had valued the property at about 25 million dollars. The Court found that it had a value of 27½ million dollars. The remaining suits are still pending before the Court for final action.

Property Held for Future Development Etc.

Outside of the property now in use are vast areas, some of it bought for protection, but most of it bought with a view to making provision for the future. The Court in the rate cases for 1903 and 1904 found a value for this property not then in use of $5,101,132
but since 1904 large additional purchase of lands
have been made at a cost, as certified by chartered
accountants to November, 1911, of $4,766,409

The present real estate holdings of the company owned outright (exclusive of lands where only the water rights are owned), exceed 100,000 acres.

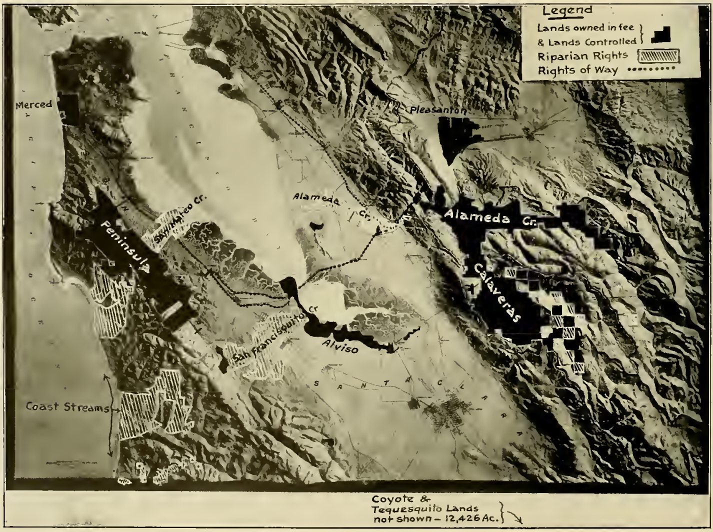
Some of this is of small value per acre, but other parts (the 2700 acres of Lake Merced lands, for example), would be of great value for subdivision if not dedicated to public use.

The values found by the Court were for rate fixing purposes and not for sale purposes and did not include "going concern" values.

Offers of Sale of Spring Valley Water Works to San Francisco

Two offers to sell the Spring Valley Water Works were submitted by said company to the City of San Francisco; one in 1877, for 16 million dollars, was rejected by the Board of Supervisors; the other, in 1910, for 35 million dollars, though accepted by the Board of Supervisors, failed by a narrow margin to secure the necessary two-thirds vote of the people at a special election held for that purpose.

A third negotiation is now under way—an informal offer of 38½ million dollars having been submitted by the city authorities to the Spring Valley Water Company on August 9th, 1912.



RELIEF MAP SHOWING LANDS, RIPARIAN RIGHTS AND RIGHTS OF WAY OWNED BY S. V. W. CO.

Appendix No. 21.

A PROPOSAL FOR THE PURCHASE OF THE SPRING VALLEY WATER WORKS BY THE CITY OF SAN FRANCISCO.

San Francisco, Cal., August 9, 1912.

Spring Valley Water Company,
375 Sutter St., San Francisco, Cal.

Gentlemen—*Regarding the Purchase of Works by the City.*—The undersigned, the Mayor and members of the Board of Supervisors of the City and County of San Francisco, the City Attorney and members of the Special Committee on Water Supply, unite in urging your company to co-operate in a friendly settlement of a long-standing controversy without further litigation or delay by selling to the city all of the water works property owned by your company for the price named below, which price is based on your offer of two years ago, and upon Judge Farrington's findings in the rate cases, with additions which we have arrived at from reasons stated below and as a matter of business judgment.

Several parts of our city are suffering from a scant supply of water from your company for fire protection; there is complaint of defective domestic supply in certain elevated sections; the natural development of certain important districts is held back because of your lack of extension of water pipes, and a well-founded belief exists that the combination of all your sources now in use, with the present transbay conduit, would fail to yield the necessary quantity should the next two or three years be of small rainfall. Our great exposition is almost at hand, and the most rapid growth that our city has known is quickly coming, and it is of paramount importance that our city should own and be in responsible control of the works that supply its homes, its commerce and its manufactories with water.

By letter of November 29, 1909, your company offered its water works property until January 20, 1910, for	$35,000,000

This offer failed of acceptance by the citizens by an extremely narrow margin in the two-thirds vote required under our charter, and for reasons so well understood that they need not be repeated here, and which are matters of the past.

If we add to this the value based on the purchase price of your real estate purchases reported by chartered accountants during 1910 and 1911, the sum of 2,219,477

we have a total of. 37,219,477

The offer of $35,000,000 made in November, must have included as a factor the value of "going concern."

Since that time you have purchased some additional property and have made some extensions of mains, these capital expenditures amounting, we understand, to about $146,196, and there has been some increase in value of your large holding of Lake Merced lands, if these could be considered as for subdivision and sale as building lots. But, on the other hand, the physical part of your plant has been depreciating, and we note that in your printed annual report to stockholders, depreciation is allowed for at the rate of $260,000 for the year 1910, also $260,000 for the year 1911.

If we add to the above valuation of $37,219,477, for the purpose of making due allowance for all factors of valuation and of all net increase in value since November 9, 1909, considered on a basis which we believe most favorable to your company 1,280,523
we have a figure of. 38,500,000

It may be noted also that this sum happens to be just 10 per cent more than the price at which you offered to sell upon January 20, 1910.

To approach this in another way, eliminating from consideration your offer of $35,000,000:

The decision of Judge Farrington, reported October, 1911, in the water rate cases for the years 1903, 1904, 1905, after allowing for physical depreciation and after weighing much evidence upon the value of component parts of your water system, found a value for that portion of the plant in use in 1903 for supplying this city, of 25,771,984

This value for rate fixing purposes did not include the value of certain properties then and now held in reserve for future use, nor did it

include "going concern" value. He found values for the property not in use aggregating	5,101,132
This included the Clear Lake property valued at	243,351
which, as we understand it, you do not now own, leaving a net value for property then unused	4,857,781
Making a total value of property used and unused, as of the year 1903	30,629,765
If we add to this, expenditures for real estate, purchases and permanent improvement, from January 1, 1904, to January, 1910, as shown by reports of the Spring Valley on file with the city	2,546,932
And the amount paid for real estate purchases during 1910 and 1911	2,219,477
We have a total of	35,396,174
But a large part of the above $2,546,932 must have been offset by physical depreciation, possibly one-third or one-half. Some parts were damaged by the earthquake, as, for example, the Pilarcitos pipe line, valued at about $300,000, of which perhaps $75,000 value was reclaimed, and the ordinary physical depreciation for which each of your two latest annual statements have allowed $260,000 per year, has been going on for two and a half years.	
If we add for going concern value and for whatever permissible increase in value of real estate that may have been over and above the obsolescence and depreciation in value of physical plant from 1904 to this date, the sum of	3,103,826
the total value today as thus found is	38,500,000

The population and your revenue from rates has increased since January 20, 1910, but the plant has become so loaded that we believe no sufficient reserve capacity in the pipes, pumps and reservoirs remains for emergencies. We believe that for some time past the actual conditions have demanded the construction of the proposed Calaveras reservoir, a new transbay conduit and a very large extension of the distributing system.

In considering the value to the city of your works as a whole, a matter of much importance is the fact that new and more complete investigations of the Spring Valley's undeveloped sources have shown, as we believe, that their capacity for a reasonable dependable extension of the supply is much smaller than had previously been supposed by city officials and citizens, as well as your own officers and stockholders, so much so that we believe work on a larger supply from the mountains must be begun very soon.

Although the value of certain of your lands, if viewed as for subdivision and sale as building lots, has probably increased since January 20, 1910, the matter of their value as a part of the water supply, involves other considerations, such as that of their not being available for sale because long impressed with a public use, and consideration must be given to the principle that such property must be valued as a whole for water supply purposes and not as an aggregate of the values of parts. While it may be true that where private property is sought to be condemned for a public purpose, the highest use to which the property may be devoted is to be considered. Yet, where a property is once devoted to a public use and it is sought simply to continue that use, the rule applied to condemnation of private property ought not to obtain. There are many difficult legal questions, the discussion of which might greatly prolong a technically precise determination of some of the elements to be considered in finding the value of the whole, and meanwhile, the interests of our city would suffer.

While it is a simple matter to agree on values of the pipes, pumps, dams and structures, and is not difficult to approximately determine the value of real estate to be used as city lots, or for agriculture, there is room for wide and endless difference of opinion on values of water rights, particularly those not yet in use and not tested by use as to capacity; and there is also room for much doubt about the rule to be followed in the enhancement of real estate value by its adaptation and use for water works purposes.

For the reasons stated above, and because promptness in large extensions of city mains and in providing a large additional supply and the ending of controversy are each elements of great value to the city, we have sought to reach a fair price in starting with the Farrington findings on values as a basis, also independently with your offer of two years ago as a basis, and adding a sum dictated by business judgment, rather than to incur delays of appraisals, arbitrations and the courts. The sum of $1,280,523 is, therefore, added to the price at which you offered to sell about two years ago, plus the cost of your acquisitions to December 8, 1911, and the sum of $3,103,826 is added to the valuation of Judge Farrington of the property used and unused as of 1903, plus cost of acquisitions from

1903 to 1911, inclusive, making the round sum of $38,500,000 for the purchase of all of the Spring Valley Water Company's physical properties, as before, with all additions used or capable of use for water supply purposes. This offer is made with the further understanding that all pending litigation between the city and your company shall be dismissed and the impounded rate funds released by the city; such settlement and release to be made, however, solely as a part of this compromise offer and without prejudice to the right of the city to further litigate the question of the disposition of such impounded funds in the event that this offer is not accepted.

The undersigned pledge themselves individually and collectively to recommend earnestly to the citizens to vote for the purchase at this price, which we believe is not only fair but liberal to your company and is reasonable and proper for the city to pay for the property and for the advantages incident to obtaining control in the immediate future in order to stop controversy.

We find from your report to the stock holders of December 31, 1911, as confirming our views of the liberality of this offer, that it covers liberal additions to the careful appraisal of the several parts of the property made a few years ago by our then city engineer, Mr. Grunsky, and he today expresses the belief that this is a fair offer; we also find that after paying par for each 4 per cent bond of your company (now quoted at $93.50), that our offer, if accepted, would make available for distribution to each of your stock holders about $71.53 for each share of stock, on which the market quotation since the fire (or since the two for one stock issue of September, 1903) has never been greater than $65, and which is now about $61, this giving to each bond holder a substantial increase over the market value of the best 4 per cent public service company bonds and 7 per cent above the present market value of your bonds, and giving to each stock holder an increase of about $10.53 per share, or about 17 per cent, above the present market value of his stock.

Should the price of $38,500,000 prove acceptable to your company and to the voters, a long time must necessarily elapse before the titles could be passed and the new administration provided for. We deem it important that the work of increasing the supply and of extending the mains should progress rapidly meanwhile. This can be accomplished by means of the resources at your command.

Upon your favorable consideration of the above, we propose to further request your company to immediately carry forward the work of constructing the Calaveras dam and reservoir, already begun by you, and to also with all speed consistent with economy, construct the line of steel pipe, 6½ feet net diameter with its connecting tunnels from the valley of the Calaveras creek to your Crystal Springs reservoir, which forms a part of the Freeman plan for the future bringing in the water of the Tuolumne river, and would in the meantime also bring in the additional supply now required. This new work to be in accord with the city's plans and specifications and at its actual cost to you plus 10 per cent, to be added to the price named above.

Upon similar terms we would also ask that the extension of distribution pipes be immediately carried forward in various districts to be specified.

We have proposed above what we believe a liberal basis of adjustment and we appeal to your shareholders and officers that controversies in water matters may cease and that mutual confidence and co-operation in the upbuilding of our city may prevail. Respectfully submitted,

(Signed) JAMES ROLPH JR., Mayor.
(Signed) PERCY V. LONG, City Attorney.
(Signed) THOMAS JENNINGS,
Chairman, Finance Committee.
(Signed) ALEXANDER T. VOGELSANG,
Chairman, Public Utilities Committee.
(Signed) CURTIS H. LINDLEY,
Advisory Water Committee.

(Signed)
CHAS. A. MURDOCK,
ADOLPH KOSHLAND,
EDWARD L. NOLAN,
J. EMMET HAYDEN,
FRED L. HILMER,
HENRY PAYOT,
DANIEL C. MURPHY,
GEO. E. GALLAGHER,
A. H. GIANNINI,
OSCAR HOCKS,
PAUL BANCROFT,
RALPH McLERAN,
BYRON MAUZY,
WM. H. McCARTHY,
GUIDO E. CAGLIERI,
Members of the Board of Supervisors.

SAN FRANCISCO, Aug. 9, 1912.—To the Hon. James Rolph Jr., Mayor of San Francisco, San Francisco: My Dear Sir—I have carefully studied the accompanying proposal to the Spring Valley Water Works, which it is contemplated will be signed by yourself, members of the board of supervisors and members of the advisory water committee, suggesting your willingness to advise the purchase of the entire plant of the Spring Valley Water Works for the sum of $38,500,000 and the release of the impounded rate funds by the city.

I have not undertaken to make a detailed appraisal from an engineering standpoint of all the integral factors constituting the Spring Valley system. This would require one or two or three months' diligent work with several assistants, but I have now for two years from time to time been studying one element and another of the Spring Valley system and have made personal inspection of all of their developed water sources and much of their physical plant—pumps, dams, etc. Some months ago I collected data from the testimony in the rate cases as to the separate value of various elements and placed these in parallel study for further analysis, so that I have a general knowledge of the property and its relation to present and future needs.

In arriving at valuations of plants of this character, the most recent practice and procedure followed in fixing the values is to deal with the properties as an entirety; regarding the tangible and intangible elements as being so interrelated that division into parts, the sum of whose separate values should be the value of the whole, is practically impossible.

It seems to me that the analysis presented in the accompanying proposal is logical and that its conclusions are sound and fair, and I strongly recommend that the proposal be made in the interest of a solution of the city's complex problems. Sincerely yours,

JOHN R. FREEMAN, Consulting Engineer.

INDEX

Page.

- Abandonment—
  - Of use of Lake Merced, 80
  - Of use of Lobos Creek, 387
- Absence—
  - Of reservoir sites, Sierra rivers, 160j
  - Of rigid sanitary restrictions, Boston water supply, 35
- Absolute right in each landowner to abstract percolating waters, 209
- Absorbing of floods, Pleasanton Valley, 86
- Absorption—
  - Alameda Creek gravels, incompleteness of, 196, 198
  - Alameda Creek gravels, limit of capacity, 196
  - Livermore Valley gravels, 88, 201
- Absorptive power of gravel intakes, 196
- Abstraction—
  - Of percolating waters, 209
  - Of water, Niles Cone, 94
- Absurdity of statement that tourists would be excluded from Hetch Hetchy, 33, 52
- Abutments, Poopenaut dam, 293
- Accessibility—
  - For repairs to pipe, 258
  - Hetch Hetchy, 289
  - Hetch Hetchy aqueduct, 239, 289
  - Moccasin Creek region, 281
  - Mt. Shasta aqueduct, 330
  - Yosemite Park through roads to be built, 15, 56
- Accident—
  - Protection against, filtered water supply, 320
  - To aqueducts, reserve against, 134
- Accidents—
  - Additional future reserves against, 65-67
  - Freedom from, New York aqueduct, 71
- Accumulations of storage, Pleasanton wells, 97
- Accustomed flood flow of stream, paramount right of owner to, 208
- Acquisition—
  - Jointly by Bay cities of Tuolumne water supply, 161-165
  - Lands and rights, McCloud River, 343
  - Of ample water rights for the future, 138
  - Of lands for San Miguel reservoir, 129
  - Of reservoir sites, 72
  - Of rights of way, 72
  - Of water rights, 72
  - Of Tuolumne County Water Company's system by Sierra and San Francisco Water Company, 304
- Act of Congress, Central Canal and Irrigation Co., 340
- Activities—
  - In use of Stanislaus water, 304, 305
  - Stanislaus River, Middle Fork, 305
- Acts for formation of municipal water districts, 164-165, 167-171
- Actual—
  - Diversion and use determines validity of water right, 342
  - Diversion and use, no right to water before, 342
  - Growth, San Francisco, 76
  - Rate of growth, Greater San Francisco, 76
  - Release for priorities less than theoretic, 104
  - Use of Tuolumne water found smaller than recorded priorities, 83
- Actual cost—
  - Los Angeles aqueduct, underestimated cost, 223
  - Truckee-Carson project tunnels, 250
  - Tunnels constructed, 250, 251
- Adams, A. L., on greater water supply, Oakland, 175
- Additional—
  - Future reserves against accident, 65-67
  - Power from releasing priorities below Moccasin Creek, 61

Page.

- Additional—
  - Quantity available for East Bay region, 97
  - Quantity available for Oakland, 97
  - Quantity available from Spring Valley sources, 97
  - Reservoirs for impounding floods, 25-27
  - Storage reservoirs possible, 68
  - Supply, Alameda Creek, 81, 83
  - Supply available, People's Water Company, 80
  - Supply available, Spring Valley Water Company, 80
  - Supply available, Union Water Company, 80
  - Supply, Bay Shore gravels, 81
  - Supply, East Bay region, 174
  - Supply from present sources, 69, 70, 97
  - Supply, Los Angeles, 80
  - Supply, Niles Cone, investigation of, 70
  - Supply, People's Water Company, 175, 176
  - Supply proposed by H. Schussler, 68
  - Supply, Spring Valley Water Co., 179
  - Supply that Spring Valley Water Company could deliver, 83, 94
  - Water resources, Bay shore gravels, 94
  - Water service required, San Francisco, 211
- Adequacy—
  - Of supply, Feather River, 349
  - Of supply, Tuolumne River, 80, 81
  - Of supply, Yuba River, 355
  - Of surplus run-off, Tuolumne River in driest years, 81
- Adequate water supply for outlying districts, plan to secure, 211
- Adit, Hetch Hetchy dam, 287
- Adits—
  - Canyon tunnel, 286
  - Groveland tunnel, 284
  - Tesla tunnel, 283
- Adjustment of disputes between overlying land owners, 205
- Administration charges omitted from first estimates, Hetch Hetchy aqueduct, 240
- Administration expenses—
  - Hetch Hetchy aqueduct divisions, 300-301
  - Hetch Hetchy project, 299
  - Los Angeles aqueduct, 227, 299
  - New York water supply, 299
- Admirable quality of workmanship, Los Angeles aqueduct tunnels, 223
- Admixture, Hetch Hetchy and Spring Valley water, 294
- Advantage of intensive farming near city, 80
- Advantageous location of San Francisco, 78
- Advantages—
  - McCloud River project, 330
  - Poopenaut dam site, 291
  - Pressure tunnels, 121
  - Tuolumne source, 72-73
- Adverse conditions—
  - Hetch Hetchy aqueduct lining, 223
  - Los Angeles aqueduct lining, 223
- Adverse public opinion aroused by court decisions, 176
- Adverse rights—
  - Alameda Creek, 96, 179, 186
  - Arroyo Valle, 96
  - McCloud River, 342
  - Niles Cone, 179, 186
  - Pitt River, 342
  - Sacramento River, 342
  - Tuolumne River, 101-104, 106-107, 285, 293
- Advisability of building—
  - Arroyo-Valle reservoir, 88
  - Calaveras reservoir, 88

Page

- Advisabillity of building—
  - Further reservoirs, or of pushing Tuolumne works...... 68, 69
  - San Antonio reservoir.... 88
- Advisable to deliver Hetch Hetchy water direct from pipes.... 62
- Advisory Board of U. S. Army Engineers—
  - Conference with.... 7, 70
  - Letter to.... 5
- Advisory Water Committee....7, 62, 395-400
- Affidavits, H. Schussler.... 192
- Aggregate yield from present sources, ultimate decrease in..... 81
- Agricultural needs—
  - Niles Cone.... 97
  - San Leandro Cone.... 97
  - San Lorenzo Cone.... 97
  - San Pablo Cone.... 97
- Agricultural uses of water.... 21, 34
- Air—
  - Currents, Coast Range.... 88
  - Pockets, tunnels.... 221
- Alameda City—
  - Branch aqueduct to.... 124
  - Adoption of proposition favoring consolidation with San Francisco.... 166
  - Wells in.... 174
- Alameda County—
  - Cities, efforts to acquire water plants.... 165
  - Communities in.... 76
  - Density of population.... 78
  - Future demands for water for.... 78
  - Future population of.... 78
  - Increase in consumption.... 78
  - Injury by heavy draft on Niles Cone.... 80
  - Irrigated acreage.... 78
  - Irrigation consumption.... 78
- Alameda Creek—
  - Additional supply from.... 81, 83
  - Adverse rights on....96, 179, 187
  - Amount of water diverted from....81, 84 86
  - Average run-off.... 91, 189
  - Backwater....180, 183, 184
  - Bridge over.... 258
  - Broad, gravelly wash of.... 258
  - Cessation of flow at time of drought.... 188
  - Concrete piers.... 258
  - Concrete pipe.... 258
  - Concrete weir across.... 258
  - Conservation of flood waters.... 84
  - Critical period of rainfall.... 204
  - Cross currents.... 82
  - Dependable yield.... 179-202
  - Discharge....84, 87, 175, 180
  - Diversions by Spring Valley.... 175
  - Draft on by Spring Valley.... 204
  - Dry years.... 196
  - Eddies.... 181
  - Evaporation....84, 91, 195
  - Flood level.... 181
  - Flood torrents....85, 86, 180, 181, 193
  - Flow....82, 84, 86-87, 91, 94, 181, 189-190, 193, 197
  - Gaugings....82, 180-183
  - Gravels.... 196-198
  - Great and sudden floods.... 87
  - Lands and water rights.... 388
  - Limited supply from underground waters.... 86
  - Local use of water....85, 91, 187, 190, 204
  - Measuring weirs.... 181
  - Necessity of storage.... 188
  - Percentage of rainfall to run-off.... 88
  - Pipe lines, successful operation of.... 123
  - Present diversion from....81, 84, 86
  - Problem, presentation by Cyril Williams, Jr.... 190
  - Rainfall contours.... 197
  - Rainfall stations....192, 194, 195
  - Relation of daily run-off to daily rainfall.... 87

Page

- Alameda Creek—
  - Reservoirs, evaporation loss.... 189
  - Retarding effect of rough, rocky bed, etc.... 82
  - Riparian rights.... 180
  - Run-off.... 91
  - Safe supply.... 190
  - Shrinkage in.... 86, 198
  - Source, date of reaching limit of for city supply.... 190
  - Sources, report by Cyril Williams, Jr.... 81
  - Section showing.... 87
  - Siphon across.... 291
  - Submarine pipes.... 383
  - Topographical map of bed.... 182
  - Torrential floods....85, 180, 188, 193
  - Unfavorable conditions for measurement of discharge... 82
  - Valley, steel pipe siphon across.... 258
  - Variability of run-off.... 196
  - Views....182-185, 203
  - Water, quality of....61, 64, 187, 194, 198
  - Waste waters.... 188
  - Watershed....172, 186, 188, 193, 197, 199, 391
  - Weirs.... 181
  - Wet years.... 196
  - Yield....83-84, 186-190, 192-193, 196, 391
- Alameda pipe line, date of construction.... 389, 390
- Alameda Water Company—
  - Negotiations for sale to San Francisco.... 385
  - Owned Calaveras reservoir site and rights.... 385
  - Owned Vallejo mill.... 385
- Alfalfa, irrigation of, Decoto.... 92, 93
- Algae—
  - From surface waters, straining of.... 61
  - Growths, foothill region, Stanislaus River.... 304
- Alkali mud, corrosive action of.... 122
- Alkaline character, California water.... 229
- Allardt, G. F., replenishment of Niles Cone.... 204
- Allowance for overhead charges, Hetch Hetchy aqueduct..... 298
- All unappropriated Tuolumne River water should be reserved for domestic supply of bay cities.... 22
- Alluvial—
  - Deposits, Alameda Creek, far from impermeable...... 200
  - Formation, San Joaquin River....111, 114, 115
- Altamont—
  - Pumping station....139, 141, 142
  - Pumping station, American-Cosumnes project.... 313
  - Pumping station, Mokelumne River project, cost of..... 368, 369
  - Reservoir.... 139, 142
  - Reservoir, Stanislaus River project.... 308
- Altered lava, Dry Creek tunnel....111, 115, 116, 276
- Alternate pipe route, Hetch Hetchy aqueduct.... 112
- Alternating daily delivery of Crystal Springs and San Andreas water.... 126
- Alternating studies for distribution aqueducts.... 123
- Alternative distribution aqueducts—
  - Cross valley connections.... 294
  - Geological sections.... 125
  - Junction point.... 294
  - Pumping station.... 294
  - Route of.... 294
  - Structures on.... 294
  - Tunnels for.... 126, 294
- Alternative pipe line—
  - Millbrae-San Mateo division.... 297
  - San Miguel-Millbrae division.... 296, 297
  - Tunnel through San Bruno Mountains.... 238
- Alternative project, filtered water supply.... 318
- Altitude—
  - Effect on evaporation.... 100
  - Testing of.... 108
- Altitudes, high—
  - Evaporation at.... 199
  - Temperature.... 199
- Alvarado bay shore—
  - Increase in draft on.... 70

INDEX

Page

- Alvarado bay shore—
  - Spoiling of water by sucking in salt ... 70
- Alvarado wells—
  - Infiltration to ... 96
  - Location of ... 96
  - Proportional yield from for east bay region ... 172
  - Yield ... 177
- Amador Canal—
  - On North Fork, Mokelumne River ... 365
  - Source of supply for Electra ... 365
- Amendments to State Constitution ... 165
- American-Cosumnes project—
  - Annual requirements for irrigation ... 311
  - Average daily yield ... 312, 314
  - Based on broad principles of conservation ... 312
  - Canal capacity ... 313
  - Comparison with Tuolumne project ... 160e, 160f, 160g
  - Cost ... 313, 314, 160f
  - Diagramatic profile of ... 160f
  - Engineering features ... 311
  - Gravity flow ... 311, 313
  - Horsepower available for general purposes ... 311
  - Horsepower required for pumping ... 311
  - Initial capacity ... 313
  - Irrigation requirements ... 313
- American-Cosumnes Source—
  - Map showing ... 310
  - Offered to San Francisco by Bay Cities Water Company ... 160e
  - Plenty of water to satisfy all needs ... 312
  - Power development ... 311
  - Power required for pumping ... 311
  - Pumping of water ... 313
  - Pumping station at Altamont ... 313
  - Quantity of water available for San Francisco ... 314
  - Rainfall map ... 312
  - Report by J. H. Dockweiler ... 311-314
  - Quantity of water required by irrigationists ... 313, 314
  - Route of pipe line ... 310
  - Run-off ... 313
  - Storage capacity ... 314
  - Tunnel capacity ... 313
  - Ultimate capacity ... 313
  - Value of Bay Cities Water Company's property ... 313
  - Water rights to be purchased ... 313
- American-Cosumnes watershed—
  - Area of ... 313
  - Distance from San Francisco ... 313, 314
- American Engineering Corporation ... 164
- American River—
  - Corporate ownership of lands ... 313
  - Industrial needs for water ... 312
  - Irrigable land dependent upon ... 311, 313, 314
  - Irrigation requirements ... 311
  - Depth to ground water in lands at mouth ... 311
  - Needs of irrigable lands ... 312
  - Priorities ... 312
  - Privately owned lands ... 312, 313
  - Purity of water ... 314
  - Reservoir sites ... 314
  - Sub-irrigated lands ... 311
  - Water ... 313
  - Watershed, rainfall ... 313, 314
- Amount available—
  - American-Cosumnes source, for San Francisco ... 313, 314
  - Feather River, for San Francisco ... 348
  - Stanislaus River, for San Francisco ... 305, 307
  - Tuolumne River, for San Francisco ... 101-107, 285, 361-363
  - Tuolumne River, to City, if priorities are restricted to maximum that can be beneficially used ... 101, 103
- Amount diverted—
  - Alameda Creek ... 81, 84, 86
  - Modesto Canal ... 359
  - Niles Cone, by People's Water Company ... 174
  - Niles Cone, by San Lorenzo Water Company ... 174

Page

- Amount of water—
  - Required for future needs ... 81
  - Right determined by actual diversion and use ... 342
  - Remaining, Tuolumne River, after satisfying all irrigation needs ... 360
  - That can be diverted from Tuolumne River by City without encroaching on prior rights ... 21
- Amphibolite—
  - Dry Creek tunnel ... 248, 278
  - Unit costs of tunneling through ... 278, 279, 281
- Ample supply from Tuolumne River ... 80
- Ample water rights for future, necessary to be secured ... 138
- Analyses—
  - Of cost, steel pipe siphons, Los Angeles aqueduct ... 230-234
  - Of water, Crockett ... 315
  - Sacramento River water ... 317
  - San Joaquin River water ... 317
- Analysis of gaugings, Tuolumne River ... 98
- Anderson bridge, over Sacramento River ... 340
- Andesite tuff ... 111, 116, 249, 283
- Angels Camp, water supply of ... 304, 305
- Angle of dip of strata ... 110
- Annexation—
  - Bay cities to San Francisco ... 165, 166
  - Berkeley to Oakland ... 166
- Annual discharge—
  - Alameda Creek ... 175
  - Stanislaus River ... 307
- Annual precipitation, Railroad Flat watershed ... 366
- Annual requirements, irrigation—
  - American River ... 311
  - Cosumnes River ... 311
  - Niles Cone ... 204
- Annual run-off—
  - Calaveras dam site ... 196
  - Sunol ... 196
- Annual yield, Railroad Flat watershed ... 366
- Anti-clines ... 110
- Antioch—
  - Filters ... 228
  - Filter tunnels, length of ... 228
  - Filter tunnels, unit costs ... 228
  - Pumping station, cost of ... 323
  - Pumping station, cost of operating ... 325
  - Water supply for ... 315
- Antonio-Valle division—
  - Description of ... 241
  - Formations ... 259, 260
  - Length of ... 241, 259
  - Structures on ... 259, 260
  - Total cost ... 260, 300
  - Unit costs ... 259, 260
- Appearance—
  - Sacramento River water ... 317
  - San Francisco water ... 317
  - Spring Valley water ... 317
  - Stanislaus water ... 309
- Appearance at Washington, Mayor of Berkeley ... 161-162
- Appendix—
  - No. 1 ... 161-166
  - No. 2 ... 167-171
  - No. 3 ... 173-178
  - No. 4 ... 199-202
  - No. 5 ... 203-204
  - No. 6 ... 205-210
  - No. 7 ... 211-220
  - No. 8 ... 221-238
  - No. 9 ... 239-301
  - No. 10 ... 302-309
  - No. 11 ... 311-314
  - No. 12 ... 315-325
  - No. 13 ... 326-344
  - No. 14 ... 345-346
  - No. 15 ... 347-354
  - No. 16 ... 355-356

Page

- Appendix—
  - No. 17 ... 357-363
  - No. 18 ... 365-372
  - No. 19 ... 373-381
  - No. 20 ... 383-394
  - No. 21 ... 395-401
- Appreciation of Tuolumne source ... 72, 73
- Appropriation of ground waters, legal difficulties ... 175
- Appropriation of percolating waters ... 205
- Appropriations—
  - D. P. Doak, McCloud River ... 329, 338, 339, 341
  - For power purposes, McCloud River ... 341
  - Of water, McCloud River ... 329, 338, 339, 341
- Appropriator rights, D. P. Doak, to McCloud River ... 341
- Appropriators, burden of proof upon to show surplus underground water ... 208
- Appropriator's right to underground water second to land owner's right ... 208
- Apricot trees, irrigation of, Niles ... 93
- Aquatic vegetation ... 129
  - Surface waters in California ... 62
- Aqueduct, Hetch Hetchy ... 252, 301
- Aqueduct tunnels—
  - Baltimore ... 121
  - Boston ... 121
  - Hetch Hetchy ... 244-249
  - Los Angeles ... 223-227
  - New York ... 121
- Arcades on highways ... 18
- Arch effect, tunnels ... 221
- Architectural treatment—
  - Hetch Hetchy dam ... 288
  - Poopenaut dam ... 291
- Arid lands—
  - Great stretches of ... 209
  - Necessity of water for ... 80
- Armstrong, B., complaint, inadequate water supply ... 218
- Arrangement of estimate, Hetch Hetchy project ... 252
- Arresting flow, Coyote River, injunction against ... 207
- Arroyo del Hambre Reservoir—
  - Capacity ... 349, 353
  - Quantities ... 349
  - Storage possibilities ... 348, 349, 353
- Arroyo las Positas, location of ... 89
- Arroyo Mocho—
  - Assumption that no water is wasted from ... 201
  - Gravels, elevation of ... 197
  - Gravels, sinkage into ... 199-201
  - Intake of ... 86
  - Location of ... 89, 113
  - Porous gravels in bed of ... 201
  - Run-off ... 196
  - Velocity of flow ... 201
  - Volume of flow ... 201
- Arroyo Valle—
  - Adverse water rights ... 96
  - Creek, gaugings ... 193
  - Creek, no dependable data as to discharge ... 88
  - Creek, priorities of Bay Cities Water Co ... 187
  - Creek, run-off ... 193
  - Dam, as to policy of building of ... 68, 69
  - Effect on Niles Cone ... 81
  - Gravels, elevation of ... 197
  - Gravels, sinkage into ... 199
  - Intake of ... 86
  - Location of ... 89
  - Rainfall ... 88
  - Reservoir, advisability of building ... 88
  - Reservoir, capacity ... 67
  - Reservoir, catchment area ... 84
  - Reservoir, evaporation ... 84, 88, 91, 189, 199
  - Reservoir, lack of data on run-off from ... 88, 91
  - Reservoir, prudency of building ... 190, 192
  - Reservoir, storage capacity ... 186, 197
  - Reservoir, temperature ... 84
- Arroyo Valle—
  - Reservoir, uncertainty as to advisability of building ... 94, 97
  - Run-off ... 196
  - Sinkage into ... 199, 200
  - Tunnel ... 247, 259, 260
- Artesian belt—
  - Diversion of water percolating in ... 205
  - Saturation with percolating water ... 205
- Artesian conditions, Livermore Valley gravels, cause of ... 200
- Artesian strata—
  - Coyote Valley, replenishment of ... 209
  - Santa Clara Valley, intake to ... 210
- Artesian water—
  - Diversion for outside use ... 205
  - Existence of, east of Pleasanton ... 201
  - Law on use of ... 205
  - Livermore Valley ... 88
  - Reasonable use of ... 205
  - Santa Clara Valley ... 206
- Artesian well owners, legal rights of ... 205
- Artesian wells—
  - Bay shore ... 206
  - Flowing ... 206
  - San Francisco ... 206
  - Sufficiency of volume for city supply ... 202
- Artificial conservation of water supplies ... 383
- Ashokan Reservoir, roads around ... 43, 44
- Asparagus, shipping of ... 77
- Assessment—
  - Modesto Irrigation District ... 360
  - Turlock Irrigation District ... 360
- Assumed base of wages, Hetch Hetchy project ... 240
- Atmospheric moisture, effect on run-off ... 194
- Attractive appearance of Alameda Creek water ... 61
- Attractiveness of region enhanced by roads to reservoirs ... 47
- Attrition, resultant pebbles and sand grains ... 202
- Audrain Lake, location of ... 310
- Authorities, law on use of percolating waters ... 205, 210
- Automatic cleaning of natural filter ... 88
- Automatic recording clock-gauges ... 123
- Automobiling around reservoirs ... 43, 45, 54
- Auxiliary storage—
  - Merced Lake ... 126
  - Poopenaut Valley ... 241
- Available—
  - Draft on cones, limit of ... 173
  - Fall, McCloud River ... 332
  - Horsepower, Grunsky plan ... 141
  - Horsepower, Freeman plan ... 141
  - Horsepower, Tuolumne River ... 31
  - Inflow, Cherry Valley reservoir ... 285
  - Inflow, Eleanor Creek reservoir ... 285
  - Inflow, Hetch Hetchy reservoir ... 285
  - Quantity of water. Tuolumne River, for San Francisco ... 285
  - Reservoir capacity, Mokelumne River ... 365, 366
  - Supply, Alameda Creek water, for cities lessened by local use ... 187
  - Supply from Stanislaus River for San Francisco ... 306, 307
  - Supply, San Francisco from Tuolumne River ... 361, 363
  - Water resources, Calaveras watershed, doubt as to extent of ... 194
  - Yield, Alameda Creek ... 179-202
- Availability—
  - For water storage, Livermore Valley gravels ... 201
  - Of surplus water for irrigation ... 21
  - Stanislaus River ... 303
- Average—
  - Daily consumption of water, San Francisco ... 383
  - Daily pumpage, Spring Valley pumping stations ... 384
  - Daily safe yield, Peninsula reservoirs ... 388
  - Daily yield, American-Cosumnes project ... 312, 314
  - Daily yield, San Pablo wells ... 176, 177
  - Discharge, Alameda Creek ... 84, 204
  - Haul, Bay Head pipe ... 236
  - Haul, Hetch Hetchy aqueduct ... 231

INDEX

Page.

- Average—
  - Natural run-off, Alameda Creek 189
  - Prices, Hetch Hetchy tunnels 246-249
  - Quantity of water delivered daily, San Francisco 384
  - Rainfall, Livermore Valley 199
  - Run-off, Alameda Creek 91
- Averaging of droughts 199
- Averaging of floods 199
- Avoiding tunneling through gravel deposits 259
- Awakening of Orient 77

- Bacheldor, Mr., complaint of inadequacy of supply 213
- Backflow of salt or brackish water 80, 81
- Backwater, Alameda Creek 180, 183, 184
- Bad ground, Hetch Hetchy aqueduct tunnels 223
- Bad spots, Hetch Hetchy aqueduct 111
- Bald Mountain ditch, carries Stanislaus water 305
- Baltimore—
  - Consumption per capita 79
  - New source sought by 187
  - Water supply, tunnels 121
- Bart Brown well, Arden, view of 93
- Bartell, M. J.—
  - Computations on yield, Tuolumne River 105
  - Gaugings, Tuolumne River 98
  - Investigation of American-Cosumnes project 160e
- Bartels, population of 335
- Basin, Livermore Valley—
  - Bottom of 201
  - Great extent of 200
  - Origin of 201
- Basis—
  - Incidental expenses, Los Angeles aqueduct tunnels 226, 227
  - Of estimate, Hetch Hetchy aqueduct 221-240
  - Of estimates, minor structures 251
  - Of unit costs, Hetch Hetchy tunnels 243, 245
- Bathing in reservoirs, forbidding of 34
- Bath tubs, increase in use of 79
- Bay Cities—
  - Co-operation to secure common water supply 161-165
  - Desire to join in development of Tuolumne water supply 138
  - Domestic supply for 22
  - Federation under borough system 165
  - Future growth 123
  - Future requirements 65, 67
  - Future safety of 22
  - Must have mountain water 71
  - Quantity of water available from McCloud River 328
  - Quantity of water required daily by 357
  - Reservation of Tuolumne River water for use of 22
  - Union of, in water district 9
- Bay Cities Water Co.—
  - Appropriators of flood waters, Coyote River 208
  - Area of water sheds 186
  - Burden of proof upon to show surplus in flood water Coyote Creek 208
  - Claim to surplus flood waters, Coyote River 208
  - Dam proposed to be built by 207
  - Development of water rights and properties 96
  - Diversion of waters of Coyote River 206-210
  - Enjoined from arresting or obstructing flow of Coyote River 207
  - Litigation with Miller 206-210
  - Maintenance of rights 96, 187
  - Mt. Hamilton supply 96
  - Offer of American-Cosumnes project to San Francisco 160e
  - Prior rights claimed by 187
  - Pumping by 207
  - Purpose of organization 206
  - Rights of 179, 186
  - Rights on Arroyo Valle Creek 187
  - Rights on Bonita Creek 187
  - Rights on Isabel Creek 187
  - Rights on Smith Creek 187
  - Shafts 207

Page

- Bay Cities Water Co.—
  - Tunnels 207
  - Value of properties on American and Cosumnes Rivers 313
  - Water rights of 96
  - Work being done by 187
- Bay communities, merging into water district 138, 144
- Bay crossing—
  - Eel River project 345
  - Feather River project 351
  - McCloud River project 331
  - Mokelumne River project 369
  - Objectionable 158
  - Objection to 321
  - Sacramento River project 320, 321
  - San Joaquin River project 320, 321
  - Stanislaus River project 308
  - Tuolumne River project 127
- Bay head pipe—
  - Average haul 236
  - Concrete lining 236, 237
  - Concrete piers 234
  - Construction of 64
  - Cost units 236, 253-254
  - Crosses Santa Clara Valley 253
  - Diameter of 253
  - Elastic limit 236
  - Field shop 236
  - Gravity flow of water 236
  - Laying submerged portion 253, 254
  - Length of 253
  - Manufacture of 236
  - Marsh flats 253, 254
  - Maximum strain 236
  - Maximum stress 237
  - Pressure upon 236
  - Salt marshes 234, 236
  - Sloughs 253
  - Submerged portion 253
  - Trestles 253
  - Unit costs 236, 253-254
  - Weight 236, 237
- Bay head pipe line—
  - Alternative route for 123
  - Cost of 253, 254
  - Field shop 231
  - Haulage of 231
  - Method of laying 123
  - Rate of delivery through 123
  - Use of labor-saving appliances 231
- Bay head siphon, unit cost 253, 254
- Bay region—
  - Excessive storage required for water supply 383
  - Future population 312
  - Intensive farming 124
  - Irrigation 124
  - Present population 312
  - Storage reserve required for 383
  - Variability of rainfall 383
- Bay shore—
  - Alvarado, increase in draft on 70
  - Artesian wells 206
  - Geology of 91
  - Gravels, additional water resources of 94
  - Gravels, deepening of draft 81
  - Gravels, quantity of water available from 81
  - Ground waters, increased use of 81
  - Lands, ownership by Spring Valley 96
  - Tunnels, unit prices 251
- Bay shore wells, yield 82, 177
- Bear Gulch power station 139, 141, 143
- Bear Gulch, siphons 139, 141
- Bear River, dams and reservoirs 160a
- Bear Valley 303
- Bear Valley dam 306
- Bear Valley reservoir, storage capacity 306

Page

- Bearing of geological studies. underground waters 191
- Beauty—
  - Of falls increased through storage 16
  - Hetch Hetchy Valley 57
  - Hetch Hetchy Valley enhanced by works 75
  - Of landscape added to by dams and reservoirs 51
- Beaver Creek, tributary of North Fork, Stanislaus River 305
- Bedrock, depression of, Livermore Valley 88
- Bed, Alameda Creek, topographical map of 182
- Beginning of construction, Hetch Hetchy dam 73, 74
- Bell avenue, San Francisco, view of 217
- Bell ranch, Decoto—
  - Irrigating 92
  - Well on 92, 93
- Belmont pumping station, capacity 384
- Below sea level, Niles Cone, plane of saturation 70
- Bench levels 108, 109
- Bench marks 108, 109
- Beneficial use of small part of Mokelumne River discharge 160b
- Beneficial use of water by irrigation districts 82, 104
- Benefits of new roads 149
- Bensley act 393
- Berkeley—
  - Annexation to Oakland 166
  - Branch aqueduct to 124
  - City Council of 161, 162
  - Defeat of annexation to Oakland 166
  - Favoring consolidation with San Francisco 166, 173-178
  - Mayor, appearance at Washington 161
  - Present sources supplying 173-178
  - Resolutions by City Council on Hetch Hetchy 161
- Berlin, rate of increase of population 76
- Bernal Heights District—
  - Complaints of inadequate water service 211, 216, 217
  - Inadequate water pressure 217
  - Lack of fire protection 211
  - No mains for fire protection 219, 220
  - Size of mains 216
- Bernal Heights tunnels, length of 131
- Berryman tunnel, yield 177
- Best mountain source, Hetch Hetchy 75
- Biddle, Colonel—
  - Member of Advisory Board of U. S. Army Engineers. 7
  - Order to investigate McCloud River 327
  - Point of intake, filtered water 315, 317
- Big Bend, flow 349
- Big Creek—
  - Line of flow 116
  - Road from Moccasin Creek 289
  - Shaft at 284
- Big Dam 304
- Big Dam reservoir 304
- Big Meadows reservoir—
  - Distance from San Francisco 347
  - Storage capacity 348, 349
- Big Meadows, volcanic ash deposits 196
- Big Oak Flat, location of 4, 116
- Biotite granite, Los Angeles aqueduct tunnels 225
- Birmingham—
  - Water supply 48, 51
  - Sanitary restrictions 33
- Bishop Estate Co., reservoir site, Stanislaus River, owned by 306
- Black Point—
  - Pumping station. reservoir supplied from 387
  - Pumps, capacity 131
- Blacksmiths' wages, Los Angeles adequate tunnels 223
- Blue Creek camp 370
- Blue Lakes—
  - Location of 370
  - Lower dam 160a
  - Rights of Pacific Gas & Electric Co. to 370
  - Rights of Sierra Blue Lakes Water & Power Co. to 370
  - Upper dam 160a
  - Water shed, area of 370
  - Water shed tributary to 370

Page

- Boarding-house, Hetch Hetchy camp, loss on 287
- Board of Engineers, Los Angeles aqueduct 223
- Board of Supervisors, San Francisco, complaints on inadequate water service 213-218
- Board of water supply, New York 299
- Board of Trustees—
  - Daly City 164
  - Redwood City 163
  - San Mateo 164
- Boating on reservoirs 49, 54
- Boats, pleasure. on reservoirs 49
- Boise River, dam at 119
- Bond issue, Modesto Irrigation District, based on Stanislaus River project 305
- Bond issues, metropolitan water districts 164, 169
- Bonita Creek—
  - Priorities of Bay Cities Water Co. on 187
  - Rights on 96
- Bonus payments cheapen cost of tunnel construction 226
- Boosters, People's Water Co 177
- Booster to San Andreas reservoir 139
- Borings—
  - Alameda Creek watershed, insufficiency of 188
  - Catskill Mountain aqueduct 71
  - Hetch Hetchy aqueduct line 264
  - Hetch Hetchy dam site 119, 287
  - Livermore Valley 192
  - On public lands, permission to make 71
  - Pleasanton Valley 191
  - Time for beginning 75
  - Tuolumne River supply necessary 70, 71
- Borough system of government, federation of Bay communities under 165
- Boston—
  - Aqueduct, moss-like growth 221
  - Consumption per capita 79
  - Metropolitan district 64
  - Metropolitan park system, reservoirs in 39
  - Metropolitan water board, highways built by 36
  - New source sought by 187
  - Progressive development 153
  - Rate of increase of population 76
- Boston reservoirs—
  - Distributing 38, 42
  - Impounding 36
  - Margins 36, 37, 38
  - Roads around 35, 36, 37, 38
  - Sanitary regulation, notices 36
- Boston water supply—
  - Campers at reservoirs 35
  - Catchment areas 35, 36
  - Population on watersheds 35, 36
  - Reservoirs 35, 37, 39, 40, 41, 42
  - Safeguards against interruption 38
  - Sanitary restrictions 32, 33
  - Sources 36
  - Tourists at reservoirs 35
  - Tunnels 121
- Bottom lands, San Joaquin River 265-269
- Boundaries—
  - East bay region 173
  - El Dorado national forest 313
  - Modesto and Turlock Irrigation Districts 83
- Bourn, W. B., courtesy of 192
- Brackish water—
  - Back flow of 80, 81
  - Infiltration of 80
  - Near Antioch 315
  - Sacramento River 317
  - San Joaquin River 31
- Branch aqueduct lines from Irvington gate house 123, 124, 255
- Branch aqueduct—
  - To Alameda 124
  - To Berkeley 124
  - To Oakland 123, 124

INDEX

Page
Branch Aqueduct—
  To San Francisco 123, 124
  Toward San Jose 123
Branch road, Hetch Hetchy to Tilltill Valley 290
Branch tunnel—
  To Crystal Springs reservoir 297
  To San Andreas reservoir 297
Branner, J. C.—
  Geology of Livermore Valley 84
  On geological refill of Livermore Valley 191
  On Livermore Valley gravels 88
  Report on geology along line, Hetch Hetchy aqueduct 110, 111
  Report on geology along proposed Lake Chabot and peninsula lines 124, 126
  Specialist on geology 109
  Studies, geological conditions, aqueduct line 221
  Value of geological studies by 198
Breadth—
  Livermore Valley gravels 201
  Storm waters, Coyote Creek 209
Bridge—
  Across San Francisco Bay 166
  Alameda Creek 258
  Arroyo Valle 199
  Hetch Hetchy dam 118
  Pitt River 327
  San Antonio dam 257
  San Joaquin River crossing 269, 270
  South Fork Canyon crossing 283
  Tuolumne River Canyon crossing 278, 279
Bridges—
  Basis of estimates on 251
  Grunsky plan 139
  Mokelumne River project, cost of 369
Bridle path to Smith's Peak 15
Briefness of storage, Alameda Creek gravels 196, 197
Brightness of prospects, San Francisco District 77
Broadening of San Francisco water supply problem 138
Brooklyn water supply—
  Over-pumping of ground waters 70, 80
  Test wells 70
Brown, Ross E., replenishment of Niles Cone 204
Bucks Bar reservoir 160e
Buena Vista District—
  Complaints of inadequate water supply 211, 215, 216
  Inadequate water pressure 216
  Lack of fire protection 211, 215
  Size of mains 216, 217
  Views of 216
Bugs from surface water, straining of 61
Building materials 72
  For roads from public lands 29
  From public lands, permit for taking 15, 22, 25
Building of roads, Hetch Hetchy project 13, 15, 240
Buildings, construction plant, Hetch Hetchy 287
Building tunnels by installments 122
Building up of San Francisco, retarded by inadequate water supply 220
Bummer Flat, dam 160a
Bummer Flat reservoir 160a
Bunk house, Hetch Hetchy 286
Burden of proof upon appropriator to show surplus supply, underground water 208
Buriburi Ridge, pressure tunnel 294
Buriburi tunnel 296
Burleson, C. M., report on Sierra Blue Lakes Water & Power Co 370
Bursting pressure, steel pipe 229
Butler, Wm. A., complaint, inadequate water supply 214
Butte County Canal—
  Area irrigated by 348
  Diversions by 348
Butte tunnel—
  Capacity 351
  Cost of 351

Page
By-pass, Crystal Springs 126, 238

Cabins, Hetch Hetchy camp 286
Cache Creek crossing, Mt. Shasta aqueduct 327
Calaveras, adverse water rights of Union Water Co 190
Calaveras-Antonio Division—
  Administration expenses 300
  Description of 241
  Length of 241, 258, 259
  Structures on 258, 259
  Total cost 259, 300
  Unit costs 258, 259
Calaveras connections 122
Calaveras Creek—
  Gaugings 82, 193
  No dependable data as to discharge 88
  Surplus flow 97
  Water priorities 187
  Watershed, area of 186
Calaveras dam—
  As to policy of building of 68, 69
  Cost of 160m
  Effect on Niles Cone 81
Calaveras dam site—
  Area tributary to 196
  Gaugings 193
  Rainfall 193
  Run-off 193, 196
Calaveras gaugings—
  Erroneous 193
  Lack of dependability in 196
Calaveras lands and rights purchased by Spring Valley Water Co 385
Calaveras quartzite 111, 116, 249
  Groveland tunnel 283
  Tesla tunnel 283
Calaveras reservoir—
  Advisability of building 88
  Capacity of 64, 65
  Catchment area 84, 88
  Conservation of flood waters by 94
  Cost of 160m
  Erroneous gaugings 88
  Evaporation 84, 189, 199
  Lack of data on run-off from 88
  Location of 112
  Plans for 64
  Immediate construction of 64
  Prudency of building 190, 192
  Safeguard in 64
  Storage capacity 197, 204
  Temperature 84
  Time advisable to start construction 179
Calaveras rights, negotiated for by San Francisco 385
Calaveras Valley, rainfall 88
Calaveras watershed—
  Doubt as to extent of available water resources 194
  Run-off 196
  Run-off proportion to that from whole Alameda Creek watershed 196
California—
  Agricultural and Improvement Co., subsidiary of Spring Valley Water Co 385
  Climatic conditions of 209
  Earthquake Commission 124
  Earthquake Commission, report of 223
  Fruit Canners' Association, complaint of inadequate water supply 215
  Gas & Electric Co., dam of 119
  In region of rather high seismicity 110
  Manufacture of cement in 242
  Neccessity of irrigation 209
  Nursery Company, Niles, irrigating scenes 92, 93
  Products, no limit to market for 77
  Uncertainty of seasons 209

Page

- California—
  - Varying rainfall 209
  - Wages of unskilled laborers 251
- Calking—
  - Bay Head pipe, cost of 236
  - Cheapness of 232
  - Los Angeles pipe, unit costs 230, 232
  - Portland aqueduct pipe 237
- Camp buildings, Hetch Hetchy 286
  - Maintenance of 287
  - Repairs to 287
  - Poopenaut Valley 291
- Camp equipment, Hetch Hetchy 286
- Campers—
  - Boston reservoirs 35
  - Exclusion of 52
  - Headquarters, Tuolumne Meadows 59
  - Paradise for 59, 60
  - Poopenaut Valley 60
- Camp grounds, Hetch Hetchy region 59, 60
- Camping—
  - Upstream from reservoirs 36
  - Upper Tuolumne 59
- Camp space, meadow near Hetch Hetchy 60
- Camp wastes, avoidance of depositing 34
- Canal capacity, American-Cosumnes project 313
- Canal—
  - Cherry Creek to Lake Eleanor 143
  - Early intake 284
  - Locations by Grunsky 108
  - Oakdale Irrigation District 303
  - Railroad Flat to Rich Gulch 367
  - Sierra and San Francisco Power Co. 305
- Canals—
  - Grunsky plan of development 139, 140
  - Los Angeles aqueduct 128
  - Manson plan 139-141, 143
  - San Joaquin Irrigation District 303-305
- Canned fruits and asparagus, shipping of 77
- Canyon Division—
  - Administration expense 301
  - Description of 241
  - Fall by series of cascades 286
  - Length of 241
  - Total cost 300
- Canyon—
  - Middle Fork, Stanislaus River 303
  - North Fork, Stanislaus River 303
  - South Fork, Stanislaus River 304
- Canyons, Stanislaus River 303
- Canyon Tunnel—
  - Adits 286
  - Cement costs 249
  - Concrete costs 249
  - Concrete lining 286
  - Cost of 286
  - Diameters 286
  - Difficulties in construction 284
  - Formation 249, 284, 285
  - Hardness of rock 284
  - Incidental costs 249
  - Length of 286
  - Percentage timbered 249, 286
  - Railway for construction 286
  - Speed of construction 286
  - Timbering cost 249, 286
  - Unit costs 249, 286
- Capacity—
  - American-Cosumnes project 313
  - Arroyo del Hambre reservoir 349, 353
  - Arroyo Valle reservoir 67
  - Bear Valley reservoir 306
  - Belmont pumping station 384
  - Big Dam reservoir 304
  - Big Meadows reservoir 348

Page

- Capacity—
  - Black Point pumps 131
  - Butts tunnel 350
  - Calaveras reservoir 64, 65
  - Chabot Lake 65, 67
  - Cherry reservoir 8
  - Clarendon Heights pumps 131
  - Clarendon Heights tank 131
  - Clay street tank 131
  - College Hill reservoir 131
  - Crystal Springs reservoir 65, 131
  - East Bay water supplies 173, 174
  - Eleanor Lake conduit 143
  - Eleanor reservoir 8, 28
  - Francisco street reservoir 131
  - Freeman plan of development 139, 140
  - Gravelly Valley reservoir 345
  - Grunsky plan of development 139, 140
  - Hale reservoir 306
  - Hetch Hetchy aqueduct 20, 294. 297, 300
  - Hetch Hetchy aqueduct tunnels 221-222, 300
  - Hetch Hetchy dam 285
  - Hetch Hetchy dam at different heights 286
  - Hetch Hetchy project 65, 67, 68, 294, 297, 300
  - Hetch Hetchy reservoir 8
  - Highland reservoir 306
  - Honda Lake 131
  - Kennedy Meadows 306
  - Kuhn's Meadow 306
  - Livermore Valley gravels 197
  - Lombard street reservoir 131
  - Los Angeles aqueduct 128
  - Manson plan of development 139, 142
  - McCloud River project 328
  - Merced Lake 131
  - Middle Fork reservoir 306
  - Millbrae-San Mateo division 297
  - Mokelumne River reservoir sites 366
  - Mt. Shasta aqueduct 327
  - Peninsula pipe line 294
  - Peninsula reservoirs 388
  - People's Water Co.'s system 177
  - Pilarcitos reservoir 65, 131
  - Pipe lines, Hetch Hetchy project, sufficient for initial development 300
  - Pleasanton Valley gravels 197
  - Poopenaut reservoir 292, 293
  - Potrero Heights reservoir 131
  - Presidio Heights tank 131
  - Precita Valley emergency pumps 131
  - Ramsey reservoir 306
  - Relief reservoir 306
  - Sacramento River project 315
  - San Andreas reservoir 65, 131
  - San Antonio reservoir 67, 256
  - Sand Flat 306
  - San Joaquin River project 315
  - San Miguel-Millbrae division 294
  - San Miguel reservoir 62, 129, 131, 132
  - Sierra and San Francisco Power Co.'s canal 305
  - Silver Valley reservoir 306
  - Stanislaus River project 308
  - Stanislaus River, South Fork, reservoir sites 304
  - Strawberry reservoir 304, 306
  - Stanislaus River project 308
  - Surplus, of Hetch Hetchy aqueduct 21
  - Table Mountain tunnel 350
  - To drink in flow, Alameda Creek gravels 198
  - Total of all reservoirs, Hetch Hetchy project 65, 67, 68
  - Tunnels, Freeman plan 140
  - Tunnels, Grunsky plan 140
  - Tuolumne County Water Co.'s system 304, 305
  - University Mound reservoir 131
  - Utica Mining Co.'s system 305, 306
  - Water plants, both sides of bay, over-estimated 69, 70

INDEX

Page

- Capacity—
  - Yuba River project 355, 356
- Capacity curve—
  - Poopenaut reservoir 292
  - San Antonio reservoir 256
  - San Miguel reservoir 132
- Capitalization, Spring Valley Water Co. 385
- Capitalized cost of operation, Feather River project 353
- Capitalized cost of pumping—
  - Eel River project 345
  - McCloud River project 160h
  - Sacramento River project 160g
  - Stanislaus River project 308
- Carquinez Straits—
  - Crossing, cost of 352
  - Crossing, Mt. Shasta aqueduct 328, 332
  - Tidal currents 350, 351
  - Width of 350, 351
- Care in avoiding depositing of wastes 34
- Care, Spring Valley water 62
- Care, Spring Valley watersheds 61
- Carrying capacity—
  - Hetch Hetchy aqueduct tunnels 221, 222
  - Hetch Hetchy pipe lines 21, 122
- Cascade, Hetch Hetchy dam 285
- Cascade Mountain water supply for Seattle 147
- Cascades, Canyon Division 286
- Case Valley—
  - Dam 370
  - Reservoir 370
- Cast iron pipe—
  - East Bay region 177
  - Great drop in price of 229
  - San Francisco 384
- Castro Street Addition, no mains for fire protection 219
- Castro Valley dike 66
  - Cost of 134
  - Site of 135, 136
  - Sketch of 136
- Catchment area—
  - Calaveras reservoir 88
  - Cherry Creek reservoir 8, 24
  - Coyote River 206
  - Eleanor Lake reservoir 8, 24
  - Eleanor Lake, uninhabitable 53
  - Hetch Hetchy reservoir 8, 24
  - Hetch Hetchy, uninhabitable 53
- Catchment areas—
  - Boston water supply 35, 36
  - Creeks on Mt. Hamilton slope 96
  - Roads in 35
  - Sewer systems on 54
  - Stanislaus River 303
  - Stanislaus River, map of 302
  - Tuolumne River 8, 24
  - Villages on 54
- Cat Point power station 313, 314
- Catskill Mountains—
  - Aqueduct from 138
  - Reservoir in 145
  - Supply for New York 138, 145
- Cattlemen's headquarters, Stanislaus River watershed 303
- Causes for rapid growth, San Francisco district 77
- Caution by signboards against pollution of reservoirs 41
- Cement coating—
  - Protection for steel pipe 229
  - Use of in New York siphons 229
  - Use of in Plymouth wrought iron mains 229
- Cement—
  - Contract prices for 241
  - Cost at Hetch Hetchy 242
  - Cost at Rosasco 242
  - Cost at San Francisco 241, 242
  - Cost of 234
  - Costs, Canyon tunnel 249

Page

- Cement—
  - Costs, Chabot tunnel 249
  - Costs, Dry Creek tunnel 248
  - Costs, Groveland tunnel 249
  - Costs, Hetch Hetchy tunnels 246-249
  - Costs, Valle tunnel 247
  - Freight charges on 241, 242
  - Lining insures longer life for steel conduit 229
  - Lining, method of applying to steel pipe 229
  - Los Angeles aqueduct tunnels, unit costs 224, 225
  - Manufacturing cost of 241
  - Manufacture of in California 242
  - Proportion in concrete 242
  - Proportion in concrete, Hetch Hetchy dam 287, 288
  - Railroad rates on 242
  - Shipping in sacks 241, 242
  - Storage shed, Hetch Hetchy, cost of 287
  - Units, Hetch Hetchy tunnels 246, 249
  - Wagon haulage, cost of 242
  - Works, Napa 242
  - Works, Suisun 242
- Central California Valley—
  - Intensive farming 77
  - Climate of 77
- Central Canal and Irrigation Co., right to divert from Sacramento River 340
- Cessation of flow, Alameda Creek, through drought 188
- Chabot Dam—
  - Cost of raising 134
  - Cross-section of projected enlargement 135
  - Enlargement, cost of 291
  - Raising of 134-136
  - Sketch of projected enlargement 135, 136
- Chabot Lake—
  - Branch line from Irvington 255
  - Capacity of 65, 67, 68
  - Cost of enlargement of 291
  - Cost per acre foot of increased storage 134
  - Gravity flow from Hetch Hetchy 134
  - Increase in capacity 62, 67, 68, 134
  - Line, difficulties of 124
  - Line, soils encountered on 124, 125
  - Location of 112
  - Route, filtered water supply 318, 322
  - Silting of 65
- Chabot Tunnel—
  - Cement costs 249
  - Concrete costs 249
  - Cost 291
  - Diameter of 249, 291
  - Excavation costs 249
  - Formations 249, 291
  - Incidental costs 249
  - Length of 249
  - Packing cost 249
  - Shafts 291
  - Timbering cost 249
  - Treacherous ground 249
  - Unit costs 249, 291
- Chain of natural lakes, American-Cosumnes project 310
- Changed conditions, water supply problem, since Garfield permit 138
- Change—
  - In location, Tesla tunnel 283
  - In route of Hetch Hetchy acqueduct through geological conditions 221, 259
- Changes—
  - From Grunsky plan by Manson 142, 143
  - From original outline of Hetch Hetchy project 160r
- Channel—
  - Sacramento River 317
  - San Joaquin River 317
- Channels—
  - Coyote River 207
  - San Joaquin River 267, 269
- Character, gravels, Livermore Valley 200

Page
- Characteristics, Stanislaus River watershed 303
- Character of rock—
  - Dry Creek tunnel 276
  - Elizabeth tunnel 223
  - Hetch Hetchy aqueduct tunnels 264
  - Hetch Hetchy aqueduct 239
  - Los Angeles aqueduct tunnels 224, 225
- Character of rocks for tunneling Hetch Hetchy aqueduct 111
- Charm, Boston parks, through reservoirs 39
- Charter does not permit city to engage in power business 31
- Chart, population 78
- Charter provisions on purchase of public utilities 63
- Charts, U. S. Coast Survey 127
- Cheap electric power, stimulus of 187
- Cheapening of cost of tunnels by paying of bonuses 226
- Cheaper cost, steel pipe 229
- Cheapest site for temporary power plant 73
- Cheap fuel oil in California 324
- Cheesman dam 104
- Cheney, Major, S. A., member California Debris Commission 340
- Cherry Creek—
  - Discharge 101-103
  - Discharge measurements 379
  - Flood-flow 143
  - Gaugings on 98, 99
  - Line of flow 117
  - Rating table 379
  - Run-off, tables on 380, 381
  - Water rights, purchase by City 138
  - Watershed, area of 8, 24, 102, 380, 381
  - Watershed, average elevation 105
  - Watershed, discharge flood flow 98
  - Watershed, mass curve diagram 285
  - Watershed, percentage of run-off to total flow of river 98, 99
  - Watershed, rainfall 105
  - Watershed, run-off 98, 101-3, 105
  - Watershed, snowfall 99, 105
  - Watershed, yield 101-3
- Cherry Creek mouth—
  - Diversion dam at 73
  - Elevation 119
  - Power house at 30, 73
  - Water level at 109
- Cherry dam—
  - Construction of 26
  - Elevation of 8
  - Gates 289
  - Gate tower 289
  - Great cost of 25
  - Height of 8, 289
  - Hydraulic sluicing 289
  - Costs 289
  - Length of 26
  - Length on crest 289
  - Masonry structure to replace low temporary one 25
  - Problems on 72
  - Quantities 289
  - Spill crest 26
  - Temporary at first 25, 26
  - Width of 8
- Cherry damsites—
  - Disadvantages of 28
  - Plan showing 26
  - Selected and surveyed 25
  - Unfavorable conditions 8, 28, 104
- Cherry diversion canal 139, 143
- Cherry rain gauge, elevation 105
- Cherry reservoir—
  - Available inflow 285
  - Costs 289
  - Depletion of storage 285
  - Draft on 26
  - Elevations 26
  - Flow line of 26
  - Inflow 33

Page
- Cherry reservoir—
  - Intake shaft 25
  - Map 26
  - Micro-organisms in 36
  - Organic life in 36
  - Outflow 33
  - Screens 289
  - Site, surveys by Ham Hall 108
  - Small storage at large cost 28
  - Storage capacity 8, 28
  - Watershed tributary to 8, 24
  - Yielding capacity 8, 104
- Cherry Valley—
  - High dam not necessary 104
  - Section of 8
- Chestnut Hill reservoir—
  - Located in populous center 38
  - Views 40, 41
- Chicago—
  - Consumption per capita 79
  - Rate of increase of population 76
- Chico formation 111, 113, 244
  - Composition of 260
  - Tesla tunnel 264
  - Valle tunnel 247, 260
- Chinese Camp—
  - Distance to mountain points 242, 289
  - Location of 116
  - Road to Groveland 289
  - Station on Sierra Railway 289
  - Traffic for Hetch Hetchy passes mainly through 289
- Chute, power house No. 2 .... 284, 286
- Cincinnati, consumption per catpita 79
- Circular section for tunnels, Hetch Hetchy aqueduct 121
- Circular cross section, facilitating construction, Hetch Hetchy aqueduct tunnels 221
- Cities bordering on San Francisco Bay 9
- City—
  - Diversion of water by 22
  - Engineer, levels by 108, 109
  - Expenditures on Hetch Hetchy by 72, 138
  - Investigation by immediately of Hetch Hetchy 72
  - Investment by on Hetch Hetchy 72, 138
  - Land purchases of 138
  - Ownership of lands 138
  - Ownership of reservoir sites 138
  - Ownership of water rights 138
  - Parks, reservoirs in 38
  - Purchase of Cherry Creek water rights 138
  - Rights of way required by 22
  - Rights purchased by 138
  - Seeks water from Tuolumne at present unutilized 53
  - Title desired by 13, 15
- City Attorney—
  - Letter of transmittal to Advisory Board of U. S. Army Engineers 5
  - On Greater San Francisco movement 165, 166
  - On the doctrine of percolating waters 205-10
  - Report on metropolitan water district for Bay cities 161-5
- City Council—
  - Berkeley 161, 162
  - Oakland 162, 163
  - Redwood City 163
  - San Jose 163
- City distributing reservoir at San Miguel 129-133
- City distributing reservoirs 384
  - Diagram showing location of 131
  - Spring Valley Water Co. 131
- City distributing system—
  - Connection with, at Islais Creek Junction 294
  - Connection with storage reservoirs 131
  - Delivery of Hetch Hetchy water into 20
  - Of Spring Valley not essential to Hetch Hetchy project 62
  - San Francisco 211, 212

Page

- City pipe system—
  - Diagram of 131
  - Diameters of 384
  - Elevation profile 131
  - Length of 384
  - San Francisco 384
  - Sizes of mains 131
  - Spring Valley Water Co. 131
- City's case, presentation of 7
- City's desire—
  - To secure rights to Lake Vernon and tributaries 58
  - To secure permit to take building materials from public lands for Hetch Hetchy construction work 15, 22
  - To secure rights of way for Hetch Hetchy construction 15, 22
  - To secure titles to lands required for roads and aqueduct 15, 22
- City's ownership of lands in Hetch Hetchy Valley 138
- City's proposed diversion not interfering with priorities of irrigation districts 83
- City's rights, protection of 72
- City's storage sometimes helpful to irrigators 83
- Civic—
  - Organizations, San Francisco Bay communities 165
  - Pride, San Francisco 77, 138
  - Welfare, San Francisco 77
- Clarenden Heights—
  - Pumps, capacity 131
  - Tank, date of construction 390
  - Tank, district served by 212
  - Tank, elevation 131
  - Tank, storage capacity 131, 390
- Clarifying of water, natural filter 201
- Clark ditch—
  - Capacity of 369
  - Heads on South Fork, Mokelumne River 369
  - Owned by Sierra Blue Lakes Water & Power Co. 369
  - Supplies Glencoe, Rich Gulch, etc 369
- Clay—
  - Cap, Niles Cone 91, 200
  - Cover, Alameda Creek gravels, far from impermeable 200
  - Deposits, Livermore Valley 200
  - Livermore Valley, sections of 89, 90
  - Livermore Valley, width of distribution 200
- Clay street tank—
  - Elevation 131
  - Location of 131
  - Storage capacity 131
- Clearing—
  - Hetch Hetchy reservoir site 286
  - Poopenaut reservoir site 291
- Clear Lake Water Co.—
  - Owned property at Clear Lake 385
  - Owned rights at Lake Merced 385
- Clearness—
  - Of Alameda Creek water 61, 194
  - Of ground waters, Pleasanton 61
  - Of ground waters, Sunol 61
- Cleveland, consumption per capita 79
- Cliffs, Hetch Hetchy, height of 6, 12
- Climate—
  - Central California Valley 77
  - Colorado 357
  - Feather River watershed 348
  - San Francisco 79
  - Yosemite National Park 56
- Clock recording rain gauges 193
- Clogging—
  - By silt of gravel conduit 200
  - Natural filter 201
  - Pores of gravel by turbid water 88
- Clough vs. Spring Valley Water Co. 85, 94, 204
- Coaching round reservoirs 49, 50
- Coagulating basins—
  - Cost of 324
  - Feather River project 352

Page

- Coagulating basins—
  - Sacramento River project 320
  - San Joaquin River project 320
- Coagulent filtration 317
- Coal mines, Tesla 110, 221, 228
- Coast Range—
  - Air currents 88
  - Crossing of 110
  - Elevations 113
  - Peaks in 113
  - Tunnels, building by installments 122
  - Tunnels, diameter of 122
  - Tunnels, hydraulic gradient of 122
  - Vapor-laden winds 193
- Coast streams—
  - Area of watersheds 392
  - Information on 96
  - Quantity available from 81
  - Undeveloped by Spring Valley 96
  - Yield 392
- Cochituate reservoir 53
- Co-efficients of roughness, Hetch Hetchy aqueduct tunnels 221, 222
- Cofferdam—
  - Hetch Hetchy dam 287
  - San Joaquin River crossing 270
- Cohen vs. La Canada Land, etc., Co. 205
- Colfax Gate, location of 4, 116
- College Hill reservoir—
  - Date of construction 387
  - Delivery of Hetch Hetchy water to 294
  - District served by 131, 212
  - Elevation 131
  - Storage capacity 131, 387
- Colorado—
  - Climate 357
  - Duty of water 357
  - Foothill reservoirs in 58
- Colorado Springs, consumption per capita 79
- Coloration of water—
  - Feather River 347
  - San Joaquin River water 317
- Columbia ditch, carries Stanislaus water 305
- Columbia, water supply of 305
- Combination of Spring Valley and Hetch Hetchy desirable 63
- Comfort, higher standards of 79
- Commercial center, San Francisco 77
- Commercial distant use of water, inferior right to local use of water 208, 209
- Commercial opportunities, San Francisco 77
- Commercial organizations, San Francisco Bay communities 165
- Commercial sale, diversion of water for 206, 207
- Commissary, Hetch Hetchy camp profit on 287
- Common labor—
  - Rate paid by Great Western Power Co. 251
  - Rate paid by Oakdale Irrigation District 251
  - Rate paid by Pacific Gas & Electric Co. 251
  - Rate paid on Los Angeles aqueduct 252
  - Rate used in Hetch Hetchy estimates 252
  - Wages in California 251
- Common law rule—
  - Applicable to percolating waters 209
  - Percolating waters 205
  - Percolating waters, not prevailing in California 209
  - Percolating waters, rejected as inapplicable 209
- Common water supply for San Francisco Bay municipalities 161-5
- Communities—
  - Alameda County 76
  - Contra Costa County 76
  - East Bay region 176
  - East Bay region, increasing demands of 97
  - Halfmoon Bay 96
  - Requirements of the several Bay 21
  - Subdivision of water among the several Bay 21
  - San Francisco Bay 76, 138
  - San Francisco Bay, future growth of 123

Page.

- Communities—
  - San Mateo County 76
  - Santa Clara County 76
- Companies acquired by or consolidated with Spring Valley Water Co. 384, 385
- Comparison—
  - American-Cosumnes project with Tuolumne project 160e-g
  - Californian conditions with those in Colorado 357
  - Cost of timbered and untimbered tunnels 245
  - Damsites 8
  - Hetch Hetchy aqueduct with Los Angeles aqueduct 128, 244, 245
  - Incidental expenses, Los Angeles and Hetch Hetchy aqueducts 226, 227
  - McCloud River project, with Tuolumne project 160i
  - Mokelumne River project, with Tuolumne project 160, 160d, 371
  - Of Freeman plan of development with those of Grunsky and Manson 138-44
  - Of plans for development, 1902 to 1912 139
  - Sources for future city water supply 152
  - Stanislaus River project with Tuolumne project 158-60
  - Tuolumne River with other sources 151-160l
- Comparative cost of timber and untimbered tunnels 242, 243
- Compartment shafts 269, 284
- Competition, purchases by Spring Valley Water Co. to prevent 384
- Complaint—
  - Inadequate water supply, B. Armstrong 218
  - Inadequate water supply, Mr. Bachelder 213
  - Inadequate water supply, W. A. Butler 214
  - Inadequate water supply, California Fruit Canners' Association 215
  - Inadequate water supply, Coso Ave. Improvement Club 217
  - Inadequate water supply, Diamond and Twenty-eighth Streets Improvement Club 217
  - Inadequate water supply, E. G. Ely 214
  - Inadequate water supply, Eureka Valley Improvement Association 216
  - Inadequate water supply, J. B. Glutz 213
  - Inadequate water supply, M. L. Grossman 213
  - Inadequate water supply, Haight & Ashbury Improvement Association 215
  - Inadequate water supply, R. G. Hamilton 214
  - Inadequate water supply, Park-Richmond Improvement Club 213
  - Inadequate water supply, Mrs. G. C. Roberts 216
  - Inadequate water supply, Southern Alabama Street and Vicinity Improvement Club 217
  - Inadequate water supply, South of Army Street Improvement Association 217
  - Inadequate water supply, A. P. Sutkamp 218
  - Inadequate water supply, Sutro Heights Improvement Club 214
  - Inadequate water supply, G. Toyne 216
  - Inadequate water supply, Twin Peaks Association of Improvement Clubs 216
  - Inadequate water supply, West End Improvement Club 218
- Complaints—
  - Improvement clubs, on inadequate water supply 211
  - Inadequate water service filed with Board of Supervisors 213-8
  - Inadequate water supply, outlying districts 211
  - Regarding inadequate water service, location of 212
- Completeness of studies, Hetch Hetchy project 134
- Composition. refill, Livermore Valley 201
- Compressor men's wages, Los Angeles aqueduct tunnels 223
- Concentrating future study and investigations on Tuolumne supply 75
- Concrete—
  - Casing, San Joaquin River crossing 270
  - Castro Valley dike 134
  - Conduit, Los Angeles aqueduct 128
  - Costs..247, 248, 249, 250, 251, 283, 284, 286, 287, 288, 295, 298
  - Cradles, San Joaquin pipe 230, 234
  - Forms for 242, 243
  - Forms, Hetch Hetchy dam 118, 288
  - Hetch Hetchy dam, ingredient units 288
  - Hetch Hetchy dam, proportion of ingredients 287, 288

Page.

- Concrete—
  - Hetch Hetchy project, mixture for 234
  - Plant, Hetch Hetchy, cost of 287
  - Proportion of cement in 242
  - Redwood tunnel, unit costs 244, 246
  - Refill, Hetch Hetchy dam 287
  - San Leandro enlargement dam 134
  - Weir, Alameda Creek 258
- Concrete lining—
  - Bay head pipe 236, 237
  - Canyon tunnel 286
  - Corbett tunnel, Shoshone project 250
  - For tunnels 21
  - For tunnels, Los Angeles aqueduct 224, 225
  - Hetch Hetchy aqueduct tunnels 120, 121, 221
  - Irvington gate house, 255
  - Klamath project tunnels 250
  - Mission Pass tunnel 255
  - New York water supply, cost of 234
  - Redwood tunnel 246, 252
  - Resistance of 239
  - Santa Clara tunnel, unit costs 223
- Concrete piers—
  - Alameda Creek 258
  - Bay head pipe 234
  - Los Angeles pipe 234
  - San Joaquin pipe line 234, 267
- Concrete pipe—
  - Alameda Creek 258
  - Feather River project 351
- Concrete work—
  - Cherry Valley dam 289
  - Eleanor dam 289
- Condemnation—
  - People's Water Co 63
  - Proceedings, New York water supply 299
  - Spring Valley property 62
- Conditions—
  - Of operation, Hetch Hetchy aqueduct 230
  - Tunneling, Hetch Hetchy aqueduct 221
- Conduit capacity, Mokelumne River project 367, 369
- Conduit line route—
  - American-Cosumnes project 310
  - Mt. Shasta aqueduct 332
- Conduits—
  - Closed 55
  - Mt. Shasta aqueduct 332
  - Spring Valley Water Co 383, 384
  - Stanislaus River project 308
- Cones—
  - Limit of available draft 173
  - Location of 174
  - Reduction of water available for 175
  - Replenishment of 173, 175
  - Saltiness of water 175
  - Seepage from creeks flowing into 173
  - Water storage capacity 175
  - Wells driven into 174
- Conferences with officials 70
- Conflagration, great 78
- Congress, Act of, Central Canal and Irrigation Co 340
- Congress street, San Francisco, view of 216
- Coniferous forests, Stanislaus River watershed 303
- Connecticut River, pipe crossing 320, 322
- Connections—
  - City Distributing System and storage reservoirs 131
  - Crystal Springs reservoir 294, 297
  - Guadalupe tunnel 296
  - Millbrae pumping station. with alternative pipe line 297
  - Potrero tunnel 296
  - San Andreas reservoir 294
  - San Bruno tunnel 295, 296
- Conservation—
  - Floods, Alameda Creek 84
  - Floods, Niles Canyon 83

INDEX

Page

- Conservation—
  - Flood water 77
  - Surplus flood water from Hetch Hetchy at Poopenaut Valley 291
- Conservatism of estimates on growth of San Francisco 78
- Consolidated city and county government 165
- Consolidation—
  - Of cities around San Francisco Bay 165, 166
  - Of water companies into People's Water Co. 177
  - Of water companies into Spring Valley Water Co. 384
- Constancy—
  - Discharge, McCloud River 330
  - Of flow 31
- Constitutional amendment 165, 166
- Construction cost—
  - Irrigation districts 360
  - Modesto District 360
  - Turlock District 360
- Construction—
  - Deferred, Moccasin Peak tunnel 260
  - Economies in, Grunsky plan 142
  - Hetch Hetchy dam, starting of 73, 74
  - Of roads, Hetch Hetchy project 281, 298
  - Of trails, Hetch Hetchy project 298
  - Plant buildings, Hetch Hetchy 287
  - Railway, temporary 290
  - Roadbeds 13, 15
  - Tunnels Hetch Hetchy aqueduct 20, 21
  - Type of, scenic road, Hetch Hetchy 19
- Construction roads—
  - Cost of Hetch Hetchy aqueduct divisions 300-301
  - Hetch Hetchy project 241
  - Poopenaut Valley 291
  - Rosasco to Hetch Hetchy 290
- Construction work—
  - Done by D. P. Doak 339
  - Hetch Hetchy project, when necessary to begin 74
  - Necessity of early start on 74
  - Necessity of new roads for 290
- Consumption of water—
  - East Bay region 173, 174
  - Palo Alto 164
  - San Francisco Bay region 312
  - Various cities in the United States 79
  - Drop in 176
- Consumption of water, increase in—
  - Alameda County 78
  - Contra Costa County 78
  - East Bay region 176
  - Marx, C. D., on 78
  - San Mateo County 78
  - Santa Clara County 78
- Consumption per capita—
  - Baltimore 79
  - Boston 79
  - Buffalo 79
  - Chicago 79
  - Cincinnati 79
  - Cleveland 79
  - Colorado Springs 79
  - Denver 79
  - Greater Oakland 79
  - Los Angeles 79
  - Milwaukee 79
  - New York City 79
  - Oakland and adjacent 79
  - Pasadena 79
  - Philadelphia 79
  - Portland, Oregon 79
  - Salt Lake City 79
  - San Diego 79
  - San Francisco 79
  - St. Louis 79
  - Washington, D. C. 79
- Contents, Poopenaut reservoir site 292

Page

- Continuance, order to show cause by Secretary of Interior 312
- Continuous flow
  - Livermore Valley gravels 200
  - Underground waters, Alameda Creek 197
- Continuous yield, Tuolumne River 8
- Contour levels—
  - Foot-hills east of San Joaquin Valley 271, 275
  - San Antonio reservoir 256
  - San Joaquin Valley 261-263, 266-268
  - Tuolumne River Canyon 277, 282
- Contour lines, Hetch Hetchy aqueduct 261-3, 266-8, 271-5, 277, 280, 282
- Contour maps—
  - Hetch Hetchy aqueduct 112-117
  - U. S. Geological Survey 108
- Contours—
  - Correction of 108
  - Eleanor Lake 108
  - Hetch Hetchy dam 118
  - Hetch Hetchy reservoir 108
  - Nines Cone 95
  - Poopenaut reservoir 293
- Contra Costa County—
  - Communities in 76
  - Density of population 78
  - Depth of irrigation 78
  - Future demands for water of 78
  - Future population 78
  - Increase in consumption 78
  - Irrigated acreage 78
  - Irrigation consumption 78
- Contra Costa Water Co. investigation by 175
- Contract cost, comparison with day labor cost 240
- Contraction joints, Hetch Hetchy dam 118
- Contractors' bond, Hetch Hetchy project 298
- Contractor's profit—
  - Antonio-Valle division 300
  - Calaveras-Antonio division 300
  - Crystal Springs-Irvington division 300
  - Hetch Hetchy project 298, 299
  - Irvington-Calaveras division 300
  - Los Angeles aqueduct 233
  - Omitted from first estimates, Hetch Hetchy aqueduct 240
  - Southern Pacific Sierra tunnels 250
  - Valle-Moccasin division 300
- Contract prices—
  - Cement 241
  - Grading 251
  - Mountain work, Southern Pacific Railroad 251
  - Mountain work, Western Pacific Railroad 251
  - Southern Pacific Sierra tunnels 250
- Contracts with Union Water Company 177
- Contract work—
  - Klamath project, Oregon 250
  - Shoshone project, Oregon 250
  - Southern Pacific bay shore tunnels 251
  - Truckee-Carson project, Nevada 250
- Control—
  - Development of power, pressure tunnels 221
  - McCloud River watershed 330
  - Power companies of Yuba River watershed 355
  - Wide fluctuations in flow 188
- Control of water during construction—
  - Hetchy Hetchy dam 287
  - Poopenaut dam 291
- Controversies with farmers, Niles Cone 91
- Converse pipe, east bay region 177
- Conveyance, Stanislaus water into Tuolumne drainage basin 305
- Corbett tunnel, Shoshone project—
  - Built by U. S. Reclamation service 250
  - Length of 250
  - Lined with concrete 250
  - Unit costs 250
- Corporate ownership of lands—
  - American River 312, 313
  - Cosumnes River 312, 313

Page

- Corrall Hollow, fault at 264
- Correction of contours 108
- Correction of levels, San Joaquin Valley 108
- Corrections of Spring Valley records by J. P. Lippincott 85
- Corrosion, steel pipe 229
- Corrosive action—
  - Of alkali mud 122
  - Upon steel of peat 319
- Cosby, Col. 7
- Coso Avenue Improvement Club, complaint, inadequate water supply 216
- Cost—
  - Alameda Creek pipe crossing 258
  - Altamont pumping station 368, 369
  - American-Cosumnes project 160f, 313, 314
  - Analyses, steel pipe siphons, Los Angeles aqueduct 230-4
  - Antioch emergency pumping station 324
  - Antioch pumping station 324
  - Bay crossing, Mokelumne River project 369
  - Bay head pipe line 253, 254
  - Bear Valley dam 306
  - Bridges 258, 279, 281, 369
  - Buriburi tunnel 296
  - Buttes tunnel 351
  - Calaveras dam and reservoir 160m
  - Calking, bay head pipe 236
  - Canyon tunnel 286
  - Carquinez Straits crossing 352
  - Cat Point power station 313, 314
  - Cement 234, 241, 242, 246-9, 250
  - Chabot dam enlargement 291
  - Chabot tunnel 291
  - Cherry Valley Reservoir 289
  - Coagulating basins 324, 352
  - Compels deferring building of large dams, Eleanor and Hetch Hetchy 25
  - Concrete 246-9, 250, 251, 258, 283, 284, 287, 288, 295
  - Concrete lining 234, 255
  - Construction plant buildings, Hetch Hetchy 287
  - Crystal Springs by-pass 298
  - Crystal Springs-Irvington division, Hetch Hetchy project 252-4
  - Dry Creek tunnel 278
  - Early intake works 284
  - Eleanor dam and reservoir 289
  - Elizabeth tunnel 223
  - Feather River dam 351
  - Feather River project 352
  - Fencing, San Joaquin Valley 270
  - Filtered water supply 324, 325
  - Filtration of Tuolumne River water 56
  - Flexible joint pipe 322
  - Fruitvale reservoir 352
  - Gravel 288
  - Gray rocks tunnel 337
  - Groveland tunnel 283, 284
  - Hale dam 306
  - Haulage 236. 242
  - Hetch Hetchy aqueduct 239-301
  - Hetch Hetchy aqueduct, lessened by steep gradient 155
  - Hetch Hetchy aqueduct tunnels, basis for estimate 221-238
  - Hetch Hetchy project 160n, 160o
  - Hetch Hetchy project, investigations to determine 71
  - Hetch Hetchy scenic road 290
  - Investigations, saved in progress of work 75
  - Irvington gate house 255
  - Kennedy Meadows dam 306
  - Loading 236
  - Los Angeles aqueduct 330
  - Los Angeles aqueduct, below estimates 223
  - Los Angeles aqueduct tunnels 224, 225
  - Maintenance. Hetch Hetchy camp 286, 287
  - Martinez and Oakland tunnel 352, 353
  - McCloud River conduit 337

Page

- Cost—
  - McCloud River diversion dam 337
  - McCloud River project 328, 338
  - Mechanical filters 324, 352
  - Middle Fork reservoir 306
  - Mission Pass tunnel 255
  - Moccasin Peak tunnel 281
  - Mokelumne River conduit 368
  - Mokelumne River diversion dam 368
  - Mokelumne River project 367-9, 371-2
  - Mortar 234
  - Oakland reservoir, filtered water supply 324
  - Packing tunnels 244, 246, 247, 248, 249, 251
  - Painting structural steel work 233
  - Pipe 278, 279, 291, 295
  - Pitt River crossing 337
  - Placing, bay head pipe 236
  - Poopenaut dam 291
  - Pumping northern sources of water supply 157
  - Railroad Flat reservoir 368
  - Railroad, Rosasco to Hetch Hetchy 290
  - Ramsey dam 306
  - Redwood tunnel 252, 253
  - Relief dam 306
  - Rich Gulch power station 368
  - Rio Vista works 324
  - Riveted pipe, McCloud River project 337, 338, 369
  - Riveting, bay head pipe 236
  - Roads, Hetch Hetchy project 281, 286, 290
  - Sacramento River crossing 324, 337
  - Sacramento River project 324, 325
  - San Andreas tunnel 297
  - San Antonio dam and reservoir 259
  - San Antonio tunnel 258
  - San Bruno tunnel 295, 296
  - Sand 288
  - Sand Flat dam 306
  - San Joaquin pipe line 269, 270
  - San Joaquin River crossing 324
  - San Joaquin River project 324, 325
  - Screens 284
  - Silver Valley dam 306
  - Stanislaus River diverting dam 308
  - Stanislaus River project 308
  - Stanislaus River storage reservoirs 308
  - Steel 231, 236
  - Steel pipe 253, 255, 258, 269, 270, 283, 351, 368-72
  - Steel plates 231
  - Stone 288
  - Strawberry dams 306
  - Submerged pipe 324, 337, 338
  - Table Mountain tunnel 351
  - Tesla tunnel 265, 269
  - Timbering tunnels 244, 246-52, 255, 258, 283, 284
  - Transmission line, Mokelumne River project 368, 369, 371, 372
  - Transportation, materials for Dry Creek tunnel 278
  - Trenching, San Joaquin River crossing 270
  - Tunneling 250, 251, 260, 265, 287, 324, 369, 372
  - Union dam 306
  - Utica dam 306
  - Valle tunnel 260
  - Yuba River project 355, 356
- Cost of operation—
  - Antioch pumping station 325
  - Feather River project 352, 353
  - Filtered water supply 325
  - Filter plants 325
  - McCloud River project 330
  - Rio Vista pumping station 325
  - Sacramento River project 325
  - San Joaquin River project 325
- Cost of power development, Hetch Hetchy project, small 31
- Cost of power transmission lines, Hetch Hetchy project, large 31
- Cost, per acre foot storage, Lake Chabot 134
- Cost, per thousand gallons, McCloud River project 330

Page

- Cosumnes River—
  - Corporate ownership of lands.... 312, 313
  - Depth to ground water on lands at mouth.... 311
  - Industrial needs.... 312
  - Irrigable land, dependent upon.... 311, 313, 314
  - Irrigation requirements.... 311, 312
  - Priorities.... 312
  - Privately owned lands.... 312, 313
  - Reservoir sites.... 314
  - Sub-irrigated lands.... 311
- Cosumnes River water—
  - Potability.... 313
  - Purity.... 314
  - Quality.... 313
- Cosumnes River watershed—
  - Rainfall.... 313, 314
- Court decisions—
  - Diversion of percolating water.... 97
  - Ground waters.... 96, 97
  - Pumping of ground waters.... 80, 81
  - Surface waters.... 97
- Courtesy of Spring Valley Water Company.... 81
- Courts—
  - Protection of rights to percolating water.... 205
  - Relief to residents for shortage of water.... 188
- Covered reservoirs for mountain supply.... 129
- Cow Creek—
  - Drop at.... 331
  - Power house.... 332
- Coyote Creek—
  - Breadth of storm waters.... 209
  - Local use of water.... 208
  - Point of diversion for San Francisco supply.... 305, 307
  - Pressure of flood waters.... 209
  - Volume of storm water.... 209
- Coyote Creek watershed—
  - Area of.... 392
  - Area owned by Spring Valley Water Company in.... 392
- Coyote River—
  - Channel.... 206
  - Connection with underground strata.... 208
  - Daily flow.... 206, 207
  - Description.... 206
  - Distant use of water.... 207
  - Diversion of waters for distant use.... 208
  - Diversion of waters of.... 206
  - Emerging from Mount Hamilton range.... 207
  - Flood waters.... 206, 207, 208, 209
  - Former channels.... 207
  - Freshets.... 206
  - Gravel bed.... 206
  - Height of banks.... 209
  - Irrigation from.... 206
  - Irrigation use of water.... 209
  - Line of flow of.... 206
  - Loss of water in bay.... 208
  - Normal flow.... 208, 209
  - Overflow of banks.... 209
  - Percolating waters.... 206-10
  - Recurring heavy rains.... 207, 208
  - Replenishment by flood waters.... 209
  - Sinking of water of.... 206
  - Source.... 206, 207
  - Source of artesian waters.... 206
  - Storm waters.... 202, 206, 208, 209
  - Sub-surface flow.... 206, 208, 209
  - Subterranean channels created by.... 207
  - Surface waters.... 207
  - Surplus waters.... 208, 209
  - Varying of course of flow of.... 207
  - Velocity of flow.... 208
  - Volumne of flood waters.... 207
  - Waste water serving no useful purpose.... 210
  - Water bearing strata.... 206
  - Water wasted in bay.... 208

Page.

- Coyote River—
  - Wet season.... 209
  - Yield.... 209
- Coyote River flow—
  - Effect of heavy rains upon.... 207
  - Increase in.... 207
  - Normal.... 208, 209
  - Sub-surface.... 206, 208, 209
  - Velocity.... 208
- Coyote River watershed—
  - Area.... 206
  - Rainfall.... 206, 207
- Coyote Valley—
  - Depletion of artesian strata.... 209
  - Gravel strata.... 207
  - Location.... 207
  - Prevention of irrigation through diversion of storm waters.... 207
  - Replenishment of artesian strata.... 209
- Coyote Valley gravels—
  - Continuous flow of water through.... 207
  - Depletion of artesian strata.... 209
  - Depth of.... 207
  - Deprivation of water through diversion.... 207
  - Direction of sub-surface flow.... 207
  - Immense quantity of water sinking into.... 207
  - Impeding flow of water.... 207
  - Lowering of water plane.... 207, 209
  - Percolation of water into.... 207
  - Replenishment of artesian strata.... 209
  - Sinking of storm waters in.... 207
  - Source of supply to Coyote River.... 207
  - Storage in.... 207
  - Water plane.... 207
- Cradles, San Joaquin pipe line.... 229
- Craig Goch dam—
  - On Elan River, Wales.... 48
  - Stores water for consumption in Birmingham, England.... 48
  - View.... 51
- Cranston, Raymond E., commendation for zeal in city's service.... 160s
- Creeks on slopes of Mt. Hamilton.... 96
- Crest, Niles dam.... 181, 182
- Crest length—
  - Big dam.... 304
  - Hetch Hetchy dam.... 286
  - Niles dam.... 181, 182
  - Strawberry Creek dams.... 304
- Crest line, Sierra Nevada mountains.... 24
- Cretaceous beds.... 124
- Critical period of rainfall—
  - Alameda Creek.... 175, 204
  - High Sierras.... 99
- Criticisms—
  - Grunsky plan of development, Hetch Hetchy.... 140-2, 144
  - Manson plans of development, Hetch Hetchy.... 142-4
  - McCloud River project.... 160h 160i
  - Mulholland's estimates on Alameda Creek yield.... 180, 201
  - Schussler's estimates on Alameda Creek yield.... 84-6, 180, 201
- Crockett Sugar Refinery—
  - Analyses of water.... 315
  - Point where water is obtained.... 315
- Crops raised by irrigation, in Modesto and Turlock districts.... 359-360
- Cross currents, Alameda Creek.... 82, 180
- Crossing—
  - Dumbarton Straits.... 123
  - San Francisco Bay.... 127
  - San Joaquin Valley, Grunsky plan.... 139, 141
- Cross-sections—
  - Elizabeth tunnel, Los Angeles aqueduct.... 223
  - Hetchy Hetchy Valley.... 146
  - Los Angeles aqueduct tunnels.... 224, 225
  - Poopenaut dam.... 293
- Croton dam—
  - Waste waters.... 187
  - Views.... 42, 43

Page.

Croton reservoir—
- Area of catchment, 53
- Population on watershed, 53
- Railroads on watershed, 53
- Tourist travel round, 54
- Views, 42, 43

Crowding of population, 77, 78
Crude gaugings by Spring Valley Water Company, 186
Crushed zones, 126
Crystal Springs by-pass—
- Cost, 298
- Diagram, 238
- Length, 297, 298
- Purpose, 126
- Unit costs, 298

Crystal Springs dam—
- Raising of, 67, 68, 252, 388
- Road over, 388
- Storage capacity, 388

Crystal Springs intake, 294, 297
Crystal Springs-Irvington division, Hetch Hetchy project—
- Administration expense, 300
- Description of, 241
- Length of, 241, 252
- Total cost, 300
- Unit costs, 252-4
- Work covered by, 252

Crystal Springs Lake division—
- Description, 240, 241
- Length, 240, 241

Crystal Springs pipe line—
- Hetchy Hetchy project, 294
- Spring Valley, 388

Crystal Springs reservoir—
- As terminal reservoir for Hetch Hetchy project, 20, 252
- Branch tunnel to, 297
- Capacity, 65
- Connections with Hetch Hetchy system, 20, 252, 294
- Connections with Irvington gate house, 252
- Crossed by wagon road, 33
- Elevation, 131
- Gate house, 252
- Gravity flow of Sunol and Pleasanton water into, 122
- Increase in storage capacity, 68, 252
- Not essential to Hetch Hetchy project, 62
- Open channel connection to, 297
- Proximity to centers of population, 252
- Records at, 84
- Sanitary safeguard if city supply stored in, 260
- Shafts, 252
- Storage capacity, 131, 204
- Undesirable conditions, 62

Crystal Springs upper dam—
- Date of construction, 388
- Height of, 388
- Raising of, 388

Crystal Springs watershed, care exercised at to preserve quality of water, 61
Cultivation, Santa Clara Valley, 209
Curvature, road from Rosasco to Hetch Hetchy, 290
Curve—
- Area, Poopenaut reservoir site, 292
- Capacity, Poopenaut reservoir site, 292
- Capacity, San Antonio reservoir, 256
- Population, 76
- Rainfall, Alameda Creek watershed, 199
- Rainfall, by Freeman, 199

Cycle of years of low rainfall, 188

Daily average yield, American-Cosumnes project, 312
Daily consumption per capita, various cities, United States, 79
Daily delivery of Hetch Hetchy aqueduct, 21
Daily discharge, Niles Canyon, 83, 84
Daily draft on Merced Lake, 383

Page

Daily gaugings—
- Arroyo Valle Creek, 193
- Calaveras Creek, 193
- Cherry River discharge, 98, 99
- Eleanor Lake discharge, 98, 99
- Hetch Hetchy discharge, 98, 99
- Laguna Creek, 193
- San Antonio Creek, 193

Daily run-off—
- Alameda Creek, past Sunol dam, 87
- Calaveras dam site, 196
- Sunol, 196

Daly City—
- Location, 164
- Resolution on Hetch Hetchy by Board of Trustees, 164

Damage to structures by earthquakes, 126, 127
Dams—
- Ashokan, 44
- Boise River, 119
- Case Valley, 370
- Cherry, 26
- Croton, 42
- Crystal Springs, 252
- Eleanor, 27
- Craig Goch, 51
- Early intake, 285
- English water supplies, 119
- Hetch Hetchy, 118
- Masonry, 119
- Mokelumne River, 160a, 366, 367
- New York water supply, 119
- San Antonio, 257
- Shoshone, 119
- Spaulding Lake, 119
- Temporary Hetch Hetchy project, 22, 73
- Vernon Lake, 16
- Wachusett, 35

Dams enhance beauty of landscapes, 51
Dam sites—
- Cherry Valley, 25, 26, 27
- Comparison of, 8
- Eleanor Lake, 23, 25
- Hetch Hetchy, 8
- McCloud River, 333
- San Antonio Creek, 257
- San Miguel, 130
- Sections of, 8
- Stanislaus River, 303, 304

Danger—
- Of interruption to service, McCloud River project, 344
- Of pollution minimized in Tuolumne supply, 33
- Of pollution, Stanislaus River, 303, 307
- Points, earthquake ruptures, 127

Data—
- Scant on Alameda Creek yield, 83
- Water companies, vague, uncertain and not dependable, 82

Day labor—
- Construction Los Angeles aqueduct, 223
- Cost comparison with contract cost, 240
- Salt River project tunnels, 250

Dead Man Canyon, cost data on steel pipe siphons laid, 230, 234
Decisions, Supreme Court, use of percolating waters, 205-210
Declivity adopted, Freeman plan, 141
Decomposed granite—
- Elizabeth tunnel, 226
- Los Angeles aqueduct tunnels, 225

Decomposition of rocks, 124
Decoto—
- Irrigation of alfalfa, 92, 93
- Views, 92, 93

Decrease—
- In discharge, Hetch Hetchy aqueduct tunnels, 222
- In output of wells, 176
- In yield, ultimate, from present sources, 81

INDEX

Page

- Deductions—
  - For local use, Alameda Creek, 85
  - From estimates on Alameda Creek yield, 186, 187, 190
- Deepening of draft—
  - Bay shore gravels, 81
  - Niles Cone, 81
- Deep gravels probably largely impervious, 88
- Deep Hollow, detour for aqueduct line through, 265
- Deer Valley—
  - Area of reservoir, 160a
  - Dam, 160a
  - Storage capacity of reservoir, 160a
- Deferring Construction—
  - Of high dams at Cherry and Eleanor, account great cost, 25
  - Of Moccasin Peak tunnel, 260
  - Of power house No. 2, 282, 286
  - Of tunnel from Hetch Hetchy dam, 22
  - Of Tuolumne works by construction of nearby reservoirs, 68, 69
- Defense against infection from pollution, 54
- Defiling of water—
  - Prevention of, 13, 34, 52
  - Public spirit against, 47
- Delay before purchase from Spring Valley could be consummated, 63
- Delivering capacity, San Joaquin Valley pipe line, 122
- Delivery conduits from sources to San Francisco reservoirs, 383, 384
- Delivery, Hetch Hetchy water—
  - To College Hill reservoir, 294
  - To Honda Lake, 294
  - To Lombard street reservoir, 294
  - To Merced Lake, 294
  - To San Miguel reservoir, 294
  - To University Mound reservoir, 294
- Delivery of water, alternating of, 126
- Delivery, rate of, tunnels, Hetch Hetchy aqueduct, 121
- Delmar street, San Francisco, view of, 216
- Delta—
  - Pinole Creek, 176
  - San Pablo Creek, 176
- Delta cones, Owens Valley, 202
- Demands, future, San Francisco, 78, 80
- Density of population—
  - Alameda County, 78
  - Contra Costa County, 78
  - Marx, C. D., on, 78
  - San Francisco, 77, 78
  - San Mateo County, 78
  - Santa Clara County, 78
- Denver—
  - Consumption per capita, 79
  - Emergency storage, 83
  - Foothill reservoirs near, 58
  - Lawns and gardens in, 79
  - Supplied by Union Water Company, 104
- Dependable yield—
  - Alameda Creek, 179, 202
  - South Fork Stanislaus River, 305
- Depleted reservoirs, refilling of, 294
- Depletion of percolating waters, 209
- Depletion of storage—
  - Artesian strata, Coyote Valley, 209
  - Artesian strata, Santa Clara Valley, 209
  - Cherry Valley reservoir, 106, 107, 285
  - Coyote Valley gravels, 209
  - Eleanor reservoir, 106, 107, 285
  - Hetch Hetchy reservoir, 106, 107, 285
  - Niles Cone, 91
  - Pleasanton Valley gravels, 198
- Depositing—
  - Of camp wastes, 34
  - Of defiling materials, 34
  - Of excrement, 34
- Depots, railroad, Rosasco to Hetch Hetchy, 290

Page

- Depreciation—
  - Equipment for bay head pipe line, 236
  - Equipment for San Joaquin Valley pipe line, 233
  - Heavy plant, Hetch Hetchy aqueduct, 298
  - Spring Valley Water Works, 385
- Depression of bedrock, Livermore Valley, 88
- Deprivation of use of water, 205
- Depth—
  - Coyote Valley gravels, 207
  - Groveland tunnel, below surface, 283, 284
  - Hetch Hetchy gorges, 287
  - Hetch Hetchy aqueduct tunnels, 111
  - Hetch Hetchy shafts, 260
  - Livermore Valley gravels, 198, 201
  - Mines, 111
  - Pleasanton Valley gravels, refilled pocket, 198
  - San Joaquin Valley shafts, 265
  - San Joaquin Valley tunnels
- Depth of evaporation—
  - High altitudes, 199
  - Livermore Valley, 199
- Depth of Irrigation—
  - Alameda County, 78
  - Contra Costa County, 78
  - Santa Clara County, 78
- Depth of precipitation—
  - Eleanor watershed, 101
  - Hetch Hetchy watershed, 101
  - High Sierras, 99
- Depth of run-off—
  - Eleanor watershed, 101
  - Hetch Hetchy watershed, 101
- Depth of water—
  - Golden Gate, 321
  - Hetch Hetchy dam storage, 285
  - Hetch Hetchy reservoir, 6, 12
  - Hetch Hetchy Valley, 9
  - Poopenaut reservoirs, 292
  - Representing reasonable use for irrigation, 359
  - Required for various crops, 357
  - San Francisco Bay, 127, 321
  - American River mouth lands, 311
  - Cosumnes River mouth land, 311
  - Modesto and Turlock districts, 358
  - Niles Cone wells, 204
- Desirable to combine Hetch Hetchy and Spring Valley, 63
- Desirability of Tuolumne water, 57
- Detention of water in storage—
  - Chief sanitary safeguard, 36, 38, 42, 43, 48
  - Crystal Springs reservoir, as sanitary safeguard, 260
  - McCloud River water, as sanitary safeguard, 343
  - Necessity of, 158
  - Stanislaus River water, 309
- Detour in Hetch Hetchy aqueduct—
  - Through Deep Hollow, 265
  - Through geological considerations, 259, 265
- Devastation by waste flood waters, Tuolumne River, 58
- Development—
  - Local sources prior to bringing in mountain water, 71
  - Sacramento Valley, importance to San Francisco, 329
  - San Joaquin Valley, importance to San Francisco, 329
- Development, Hetch Hetchy—
  - Initial capacity, 300
  - Should precede development of Eleanor or Cherry Creeks, 154
  - Ultimate capacity, 300
- Development of power—
  - American-Cosumnes project, 311
  - Feather River, 100
  - Freeman plan, 141
  - Grunsky plan, 140, 141
  - Hetch Hetchy aqueduct, 128
  - Los Angeles aqueduct, 128
  - Manson plan, 143
  - McCloud River project, 327, 344

Page

- Development of power—
  - Tuolumne River project 22, 29, 31, 109, 116, 280, 282, 286
- Development of storage, point beyond which impracticable 187
- Development of underground storage, Livermore Valley 86. 88
- Development of water resources—
  - Livermore Valley 193
  - Pleasanton Valley 193
- Development of water supply, order of 62, 75
- Development plans—
  - Comparison of 138-44
  - Freeman 139-42, 144
  - Grunsky 139-42, 144
  - Manson 139-42, 144
  - Plans of 1902 wholly unsuitable for 1912 140
  - Under Garfield permit 138
- Development work after favorable decision from Washington 160r
- Diagramatic profile—
  - American-Cosumnes project 160f
  - Mokelumne gravity project 160c
- Diagram—
  - City Distributing Reservoirs 131
  - City Pipe System 131
  - Comparison of dam sites 8
  - Connections between city distributing system and storage reservoirs 131
  - Crystal Springs by-pass 238
  - Discharge, Sunol dam 184
  - Hardness of river waters 316
  - Hetch Hetchy aqueduct capacities 222
  - Hetch Hetchy pipe location 262, 263
  - Hetch Hetchy tunnel location 261
  - Hetch Hetchy, Eleanor and Cherry catchments 285
  - Niles dam 181
  - Probable rate of increase in population San Francisco district 76
  - Rainfall in High Sierras 99
  - Ratio of mean monthly discharge, City catchments to La Grange 99
  - Relation of flow, Tuolumne River, available to City to that needed for priorities 101, 103
  - San Antonio reservoir 256
  - Solids in river waters 316
  - Stanislaus River drainage basin 302
  - Stanislaus River project 309
  - Water available to San Francisco from Stanislaus River drainage area 306
  - Yield available to City from Eleanor and Cherry reservoirs 107
  - Yield available to City from Hetch Hetchy reservoir 106
- Diamond and Twenty-eighth Streets Improvement Club, complaint, inadequate water supply 216
- Diamond drill borings—
  - Exploration by 122
  - Necessity of 71
- Difficulties—
  - In building roads 72
  - In construction, Canyon tunnel 284
  - In construction, Tesla tunnel 283
  - Of transportation 119
- Dikes—
  - Sacramento River 77
  - San Joaquin River 77
- Diligent—
  - Prosecution of work on water rights 341
  - Work on Hetch Hetchy dam 74
- Diminution, stream flow 205
- Dip—
  - In formations, Hetch Hetchy aqueduct line 264
  - Livermore gravels 259
  - Of strata 110
  - Sunol gravels 259
- Direction of flow, percolating waters 94
- Disadvantages—
  - Cherry Valley dam site 28
  - Eel River project 157

Page

- Disadvantages—
  - Eleanor Lake dam site 28
  - Feather River project 157
  - Long storage in California climate 160i
  - McCloud River project 157, 330, 343-344
  - Partially empty reservoirs 187
  - Sacramento River project 160g
  - Stanislaus River project 308-309
  - Steel pipe compared with tunnels 155
  - Yuba River project 157
- Disagreement between Duryea and Spring Valley gaugings 193
- Disaster consequent upon shortage in domestic water supply 188
- Disbursements—
  - Peoples Water Company 177
  - Spring Valley Water Company 385
- Discharge—
  - Alameda Creek 82, 84-85, 87, 180, 188
  - Cherry Creek 101-103, 379
  - Coyote River 206-207
  - Eleanor Creek 101-102, 377
  - Feather River, North Fork 348-349
  - Hetch Hetchy 101-103
  - Hetch Hetchy aqueduct tunnels 221-223
  - Hetch Hetchy dam site 373
  - La Grange 99-100, 101-103
  - McCloud River 329, 334-335, 339-340
  - Mokelumne River 365
  - Stanislaus River 307
  - Tuolumne River 101-103, 373
  - Yuba River 355
- Discoloration of water—
  - McCloud River 329, 334
  - Mud Creek 334
- Discrepancies between estimates of Williams, Schussler and Mulholland 190
- Diseases, water-borne 33, 36, 37, 42
- Distance—
  - American-Cosumnes headwaters to San Francisco 313-314
  - Big Meadows, from San Francisco 347
  - Cherry reservoir to San Miguel reservoir 128
  - Chinese to Groveland 242
  - Chinese to Priest's Hill 242
  - Crystal Springs to San Miguel reservoir 128
  - Early Intake to Crystal Springs reservoir 128
  - Hetch Hetchy aqueduct to railroads 289
  - Hetch Hetchy to Cherry reservoir 128
  - Hetch Hetchy to Early Intake 128
  - Hetch Hetchy to Hog Ranch 289
  - Hetch Hetchy to Poopenaut Valley 293
  - Irvington to Lake Chabot 290
  - Modesto and Turlock Districts from San Francisco 358
  - Owens River intake to Los Angeles 128
  - Salt water extends up stream 315
  - San Francisco Bay, across 127, 321
- Distant Use—
  - Artesian waters 205
  - Coyote River 207-208
  - Percolating waters 205
- Distributing ditch, Stanislaus water used in Tuolumne drainage basin 305
- Distributing reservoirs—
  - Boston 35-41
  - Location of 131, 212, 389-390
  - Peoples Water Company 177
  - Spring Valley Water Company 62, 131, 212, 389-390
- Distributing system—
  - Peoples Water Company 177
  - Spring Valley Water Company 131, 212, 389-390
  - Union Water Company 177
- Distribution—
  - Of gravels, Livermore Valley 200
  - Of rainfall 88, 190, 193
  - Of water among the different communities 21, 123
  - Of water by wagons and carts, San Francisco 386
- Disturbance of rocks, Corral Hollow 264
- Ditches—
  - Mokelumne River region 365, 370

INDEX

Page

- Ditches—
  - Tuolumne County Water Company, 304
  - Tuolumne drainage basin conveying Stanislaus water, 305
  - Utica Mining Company, 304
- Diversion canals—
  - Carrying capacity of, 193
  - Manson plans, 139, 143
  - Mokelumne River, 367
- Diversion dam—
  - Cherry Creek, 73, 143
  - Early Intake, 22, 282, 284
  - McCloud River project, 337
  - Mokelumne River, 367
  - Stanislaus River, 307
  - Temporary, 22
  - Tuolumne River, 139, 143
  - Yuba River, 356
- Diversion points—
  - Feather River, 345
  - McCloud River, 327, 331-332
  - Yuba River, 356
- Diversions of water—
  - Alameda Creek, 81, 84, 86, 175, 204
  - Cherry Creek, 25
  - Coyote River, 207-208
  - Eleanor Lake, 23
  - Feather River, 348
  - Niles Cone, 70
  - Percolating waters, 205
  - Sacramento River, 340
  - Stanislaus River, 305
- Diversity in rainfall, 193
- Divisions of Hetch Hetchy aqueduct, 240-241
- Doak proposition, McCloud River—
  - Appropriations made, 338-339
  - Construction work done, 339, 341
  - Criticism by John R. Freeman, 342-343
  - Criticism by C. E. Grunsky, 332-333, 338-341
  - Criticism by Curtis H. Lindley, 341-342
  - Offer to sell properties and rights to San Francisco, 327-330
  - Rights claimed, 341
- Dockweiler, J. H.—
  - Commendation for zeal in City's service, 160s
  - Population studies by, 76, 312
  - Report on American-Cosumnes project, 311-314
  - Report on east bay region, 82, 173-178
  - Report on Modesto and Turlock Irrigation Districts, 357-363
  - Report on Niles Cone, 80, 82, 91 94, 203-204
- Doctrine of percolating waters, 205-210
- Domestic—
  - Purposes, use of water for, 21
  - Supply for bay cities, 22
  - The highest use for water, 21-22
  - Water supply, disaster consequent upon shortage in, 188
- Domination of political interests, effect on wages, 252
- Donnell's Flat, 303, 306
- Doubtful ground, Hetch Hetchy aqueduct line, 221, 223
- Doubtful points, water supply, construing on side of safety, 188, 190
- Dove Creek pipe line, 230
- Downey street, San Francisco, view of, 216
- Draft—
  - Alameda Creek, 204
  - Bay shore gravels, 81
  - Cherry Valley reservoir, 26
  - Cones, 173
  - Coyote Valley gravels, 209
  - Eleanor reservoir, 27
  - Hetch Hetchy reservoir, 11, 13
  - Niles Cone, 70
  - On reservoirs, 65, 67
- Drainage areas—
  - (See "catchment areas")
- Drainage—
  - Elizabeth tunnel, 223
  - Modesto and Turlock Districts, 359
  - Sunol Valley gravels, 86
- Drill runners' wages, Los Angeles aqueduct tunnels, 223

Page

- Drop
  - At Knight's Ferry, 307-308
  - At Rich Gulch power house, 366
  - Between Hetch Hetchy and Early Intake, 284
  - Cow Creek power house, 332
  - Early Intake, 282
  - In consumption of water, 176
  - In consumption through meters, 79
  - In tunnels, Hetch Hetchy aqueduct, 221
  - McCloud River, 331
  - Moccasin Creek, 260
  - Stanislaus water, 305
  - Tesla tunnel, 281
- Drought—
  - Averaging of, 199
  - Cessation of flow Alameda Creek through, 188
  - Periods of, 99-100, 103-104, 106-107
  - Reserve against, Denver, 83
- Drowning of weirs, 181
- Dry Creek, 199-200
- Dry Creek crossing, 278
- Dry Creek power station, 139, 141, 143
- Dry Creek tunnel—
  - Cost of, 278
  - Formations, 248, 276, 278
  - Length of, 248, 276
  - Location of, 276
  - Location revised, 278
  - Percentage timbered, 248, 276, 278
  - Shafts, 278
  - Treacherous ground, 276
  - Unit costs, 248, 278
- Dry—
  - Periods, High Sierras, 99, 100
  - Years, Alameda Creek, 196
  - Years, series of, 186
- Drying—
  - Up of streams, 209
  - Up of wells, Niles Cone, 204
- Ductility, steel pipe, San Joaquin Valley, 229
- Dumbarton—
  - Narrows, pipe line across, 20
  - Point, 253, 308
  - Straits, 123
- Durability—
  - Marshes, 123
  - Pipe exteriors California climate, 229
  - Schussler's wrought iron pipe, 122
  - Steel pipe, 122
  - Wrought iron pipe, 122
- Durham Bridge, water level, 266
- Duryea, Edwin, Jr.—
  - Disagreement with Spring Valley gaugings, 193
  - Estimates of yield, 186
  - Measurements by, 82
  - Studies and gaugings by, 192
- Duty of water—
  - East Colorado, 357
  - Modesto and Turlock Districts, 357
  - Niles Cone, 94, 204
  - Santa Clara Valley, 392
- Dwellings, Hetch Hetchy, 286

- Early Intake—
  - Cost of works at, 284
  - Dam, 282, 284-285
  - Drop at, 282
  - Elevations, 109, 282
  - Flume, 284
  - Headworks, 284
  - Location, 4, 117, 282
  - Power house site at, 108
  - Recovery of Poopenaut Valley water, 293
  - Rights of way for, 22
  - Roadway, 282
  - Screens, 282, 284
  - Surveys for, 109

Page

- Earning capacity, Hetch Hetchy ... 142
- Earth dam—
  - Cherry Valley ... 26, 289
  - Eleanor Lake ... 23, 25, 27
  - San Antonio ... 259
- Earthquake—
  - Danger to Hetch Hetchy aqueduct ... 110-111
  - Effect of ... 123
  - Faults ... 323
  - Intensity of shocks ... 109-110
  - Pipes injured by ... 127
  - Rifts ... 126
  - Ruptures ... 127
  - Safety against ... 126-127
  - Shocks ... 109-110
  - Water structures not injured by ... 126-127
- East bay region—
  - Additional quantity of water available for ... 97
  - Boundaries of ... 173
  - Communities in ... 97, 176
  - Consumption of water by ... 173-174, 176
  - Map of area served ... 172
  - Population of ... 173-174
  - Present sources ... 173-178
  - Report on by J. H. Dockweiler ... 82, 173-178
  - Proportional supply ground and surface waters to ... 172
  - Water companies supplying ... 174
- East bay water supplies, capacity of ... 173-174
- Eastman, S. P. ... 192, 200
- Eastwood, Mr., commendation for zeal in City's service ... 160s
- Echo Lake, location of ... 310
- Economical order of construction ... 119
- Economy in construction—
  - Grunsky plan ... 142
  - Of dams ... 119
- Eddies—
  - Alameda Creek ... 181
  - Retarding effect of ... 82
- Eel River—
  - Controlled by Snow Mountain Water and Power Company ... 345
  - Fall ... 345
  - Project ... 345-346
  - Report on, by C. E. Grunsky ... 345-346
  - Route of conduit from ... 345
- Effect—
  - Of complete metering ... 176
  - On Niles Cone by building dams ... 81
  - On quality of water from storage ... 32
- Effluents, filtration of ... 34
- Elan River ... 48, 51
- Elastic limit—
  - Bay head pipe ... 236
  - Hetch Hetchy pipe ... 236
  - San Joaquin pipe ... 236
- Elder Creek crossing, Mt. Shasta aqueduct ... 332
- El Dorado National Forest, boundaries of ... 313
- Eleanor-Cherry Division—
  - Cost of ... 289, 300
  - Description of ... 241, 289
  - Length of ... 241, 289
  - Structures on ... 289
  - Unit costs ... 289
- Eleanor-Cherry tunnel—
  - Building of ... 119
  - Gatehouse ... 25
  - Length of ... 289
  - Percentage timbered ... 289
  - Route of ... 117
  - Shafts ... 25, 289
  - Unit costs ... 289
- Eleanor Creek—
  - Discharge measurements ... 377
  - Line of flow ... 117
  - Rating table showing run-off ... 377
  - Run-off ... 378-379

Page

- Eleanor Creek watershed—
  - Area of ... 8, 24, 102
  - Discharge ... 98
  - Elevation ... 105
  - Forest growth in ... 53
  - Granitic areas in ... 53
  - Insolubility of rock ... 53
  - Mass curve diagram on ... 285
  - Melting snow ... 105
  - Precipitation ... 101
  - Rainfall ... 99, 105
  - Run-off ... 98 101-103, 105
  - Smallness of ... 23
  - Snowfall ... 28, 99
  - Uninhabitable ... 53
  - Yield ... 101-103
- Eleanor dam—
  - Concrete work ... 289
  - Construction of ... 23
  - Cost of ... 142, 143, 289
  - Elevation ... 8
  - Freeman plan ... 139
  - Gate house ... 289
  - Gates ... 289
  - Great cost of ... 25
  - Grunsky plan ... 139
  - Height of ... 289
  - Hydraulic sluicing ... 289
  - Length on crest ... 289
  - Manson plan ... 139, 142
  - Masonry structure to replace low temporary one ... 25
  - Problems of ... 72
  - Quantities ... 289
  - Spill crest ... 27
  - Temporary at first ... 23, 25, 27
  - Width of ... 8
- Eleanor dam (temporary)—
  - Elevation of ... 27
  - Hydraulic fill ... 27
  - Length of ... 27
  - Plan of ... 27
- Eleanor dam site—
  - Disadvantages of ... 28
  - Map ... 27
  - Unfavorable as to length and cost of dam ... 8, 104
  - Unfavorable conditions ... 28
- Eleanor development should be preceded by Hetch Hetchy development ... 154
- Eleanor Lake—
  - Conduit ... 143
  - Contours ... 108
  - Dam site ... 23, 25
  - Discharge ... 101-103
  - Evaporation ... 306
  - Gaugings ... 98, 99
  - High dam not necessary ... 104
  - Map ... 27
  - Permanent masonry dam ... 25, 27
  - Proposed temporary power plant at ... 160r
  - Rain gauges ... 101
  - Sanitary survey ... 53-55
  - Temporary earth dam ... 25, 27
  - Tunnel under ... 25, 27
  - Use first of ... 142, 143
  - View of ... 23
- Eleanor Lake water—
  - Micro-organisms in ... 36
  - Organic life in ... 36
- Eleanor main canal ... 139
- Eleanor rain gauge, elevation ... 105
- Eleanor reservoir—
  - Available inflow ... 285
  - Catchment area ... 8, 24
  - Cost ... 289
  - Depletion of storage ... 285

INDEX

Page

- Eleanor reservoir—
  - Draft upon 27
  - Flow line 27
  - Freeman plan 139
  - Grunsky plan 139
  - Inflow 33
  - Intake shaft at 25
  - Manson plan 139
  - Map 27
  - Outflow 33
  - Screens 289
  - Small watershed and expensive dam 28
  - Storage capacity 28
  - View of 23
  - Watershed tributary to 8, 24
  - Yielding capacity 104
- Eleanor Valley, section of 8
- Elections, consolidation of bay cities 165, 166
- Electricity supplied from Amador Canal 365
- Electrical power transmission lines 15
- Electric haulage—
  - For Eleanor-Cherry tunnel 119
  - Modern methods 226
- Electric power—
  - For Dove Creek pipe line, cost 230
  - For San Antonio pipe line, cost 230
  - Stimulus of cheap electric power 187
- Electro-chemical manufacturing processes, discovery of 32
- Elements of cost, San Joaquin pipe line 230, 231
- Elevation—
  - Alameda Creek gravel deposits 197
  - Arroyo Mocho Valley gravels 197
  - Arroyo Valle gravels 197
  - Cherry dam 8
  - Cherry rain gauge 105
  - Cherry River mouth 109
  - Cherry River watershed 105
  - Cherry Valley reservoir 26
  - City distributing reservoirs 131
  - Clarendon Heights tank 131
  - Clay street tank 131
  - Coast Range 113
  - College Hill reservoir 131
  - Crystal Springs reservoir 131
  - Early intake 109, 282
  - Eleanor dam 8
  - Eleanor Lake 27
  - Eleanor rain gauge 105
  - Feather River diversion dam 350
  - Francisco street reservoir 131
  - Hetch Hetchy aqueduct 112-117
  - Hetch Hetchy dam 8, 118, 285
  - Hetch Hetchy dam outlets 11, 13
  - Hetch Hetchy Valley floor 11
  - Hog Ranch 105
  - Honda Lake 131
  - Incorrect on maps 108, 109
  - Livermore Pass 323
  - Livermore Valley gravels 197
  - Lombard street reservoir 131
  - McCloud River intake 332
  - Merced Lake 131, 383
  - Moccasin Creek mouth 108
  - Moffatt Bridge 108
  - Oroville 347
  - Peoples Water Company's reservoirs 177
  - Peoples Water Company's service areas 177
  - Pilarcitos reservoir 131
  - Pleasanton Valley gravels 197
  - Poopenaut dam 293
  - Poopenaut reservoir 292
  - Potrero Heights reservoir 131
  - Portolacca 105
  - Power house No. 1, Hetch Hetchy project 29, 109
  - Priests Hotel 109

Page

- Elevation—
  - Presidio Heights tank 131
  - Rich Gulch power house 366
  - Red Mountain Bar 108
  - San Andreas reservoir 131
  - San Antonio dam 257
  - San Antonio reservoir 256
  - San Joaquin River 266-268
  - San Miguel reservoir 65, 129, 131, 132
  - Stanislaus River diverting dam 307
  - Suisun Point reservoir 328
  - Tuolumne Meadows 59
  - Tuolumne River 108, 109
  - Tuolumne River, mouth of South Fork 109
  - University Mound reservoir 131
- Elevation average—
  - Eleanor Creek watershed 105
  - Hetch Hetchy watershed 105
- Elimination—
  - Of impurities by storage 53
  - Of mosquitoes produced in swamps, Hetch Hetchy Valley, by flooding 56
  - Of open canals, Freeman plan 142
  - Of pumping, Freeman plan 142
  - Of trestles, Freeman plan 142
- Elizabeth tunnel, Los Angeles aqueduct—
  - Areas of cross sections 223
  - Character of rock 223
  - Comparison with Hetch Hetchy tunnels 128
  - Cost data 223
  - Cost of concrete lining 223
  - Diameter 223
  - Difficulties in excavation 226
  - Excavation costs 223
  - Granitic formation 226
  - Incidental costs 223
  - Length 223
  - Method of excavation 226
  - Natural conditions 223
  - Period of construction 226
  - Progress made on work 226
  - Rate of progress 226
  - Re-timbering 226
  - Timbering 223, 226
  - Unit costs 223, 226
- Elongation, steel pipe, San Joaquin Valley 229
- Ely, E. G., complaint on inadequate water service, San Francisco 215
- Embankment—
  - Bay head pipe 254
  - San Joaquin River bottom lands 269, 270
- Emergency gates, Hetch Hetchy dam 285
- Emergency intake, filtered water supply 319
- Emergency storage—
  - Denver 83
  - Hetch Hetchy project 28
  - Merced Lake 126
- Employers' liability insurance—
  - Hetch Hetchy project 298
  - Rate of premium 298
- Emptying—
  - Hetch Hetchy reservoir 10
  - Honda Lake 387
  - Underground reservoir 80, 81
- Enforcing of sanitary regulations 34, 36
- Engineering costs—
  - Bay head pipe 236
  - Hetch Hetchy aqueduct divisions 300-301
  - Hetch Hetchy project 299
  - Los Angeles pipe 233
  - New York water supply 299
  - San Joaquin pipe line 233
- Engineering features, American-Cosumnes project 311
- Engineering reconnaissance by Freeman 71

Page

- England—
  - Dams in 119
  - Reservoirs in 46, 47
- Enhancement of beauty of landscape by dams and reservoirs 51
- Enlargement of Chabot dam 97
- Ensign Act 386, 393
- Ensign, George H.—
  - Franchise secured by 386
  - Incorporated Spring Valley Water Works 386
- Equalization of flow—
  - Eel River 345
  - Stanislaus River 305
  - Yuba River 355
- Equalizing action of pumps 38
- Equalizing basin, San Joaquin Valley 265
- Equalizing reservoir—
  - Moccasin Creek Valley 31
  - Near Fruitvale 350
  - San Joaquin Valley pipe line 269
- Equal rainfall, lines of 197
- Equipment—
  - Hetch Hetchy aqueduct 298
  - Hetch Hetchy camp 286
  - Hetch Hetchy pipe lines, haulage 231
  - Los Angeles aqueduct, steel siphons 230
  - Los Angeles aqueduct tunnels 227
  - Los Angeles pipe 233
  - San Joaquin pipe 233
- Equipment cost—
  - Dove Creek pipe line 230
  - Hetch Hetchy aqueduct 270
  - San Antonio pipe line 230
- Erosion—
  - Livermore gravels 259
  - Sunol gravels 259
- Erroneous Calaveras gaugings 88, 193
- Errors—
  - In computation, flood flow, Alameda Creek 188
  - In estimates, Alameda Creek yield 186-190
  - In records of Spring Valley Water Co. 84, 85
- Esopus watershed, New York State 53, 145
- Established rights—
  - Mokelumne River 366
  - Stanislaus River 304, 305
- Establishing of servitude 34
- Estimated growth—
  - Greater San Francisco 76
  - San Francisco 76
- Estimated increase in population, San Francisco bay communities 312
- Estimates, Alameda Creek yield—
  - By H. Schussler 186
  - By Cyril Williams, Jr. 186
  - Deductions from 186-190
  - Discrepancies, estimates of Mulholland, Schussler and Williams 186-190
  - Errors in 186, 190
  - Scant data for 192, 193
  - Schussler's estimates theoretically impossible 84
- Estimates on cost—
  - Enlargement of Lake Chabot 134
  - Filtered water supply 324, 325
  - Hetch Hetchy aqueduct 239-301
  - Hetch Hetchy aqueduct tunnels....243, 249, 252, 255, 258, 259, ...260, 264, 265, 276, 278, 279, 281, 283, 284, 286, 295, 297
  - Hetch Hetchy aqueduct tunnels, basis of 221-38
  - Hetch Hetchy project....160n, 160p, 300-1
  - Manson's estimates on Hetch Hetchy too low 143
  - Mokelumne River project....367, 368, 369, 371, 372
  - Sacramento River project 324, 325
  - San Joaquin River project 324, 325
- Estimates of flow, Stanislaus River 307
- Estimates on population, Greater San Francisco 77
- Eureka ditch, carries Stanislaus water 305
- Eureka Valley 303

Page

- Eureka Valley Improvement Association, complaint on inadequate water supply, San Francisco 215
- European cities, increase in use of water in 79
- Evaporation—
  - Alameda Creek 195
  - Alameda Creek reservoirs 180
  - Alameda Creek system 84
  - Altitude effect on 100
  - Arroyo Valle reservoir....84, 88, 91, 199
  - At night 199
  - Calaveras reservoir 84, 199
  - Effect on of temperature 100
  - Eleanor Lake 306
  - High altitudes 100
  - High altitudes, experiments on 199
  - Livermore Valley 85
  - Livermore Valley water surfaces 199
  - Pleasanton Valley 85
  - Rainfall 195
  - Rate of 190
  - Recording of 100
  - San Antonio reservoir 84, 199
  - Through irrigation 189
  - Through plant transpiration 189
  - Winter 199
  - Evaporation lessened at night in high altitudes 199
- Evaporation loss—
  - Alameda Creek 91
  - Alameda Creek reservoirs 189
  - Pleasanton swamp land 199
- Exaggeration of reserves—
  - People's Water Co. 82
  - Spring Valley Water Co. 82
- Example—
  - Of Boston distributing reservoirs 38, 42
  - Of Boston metropolitan impounding reservoir 36
  - Of New York impounding reservoirs 43-45
  - Of San Pablo Cone 176
- Excavation costs—
  - Alameda Creek siphon 291
  - Bay Head pipe 236
  - Buriburi tunnel 296
  - Canyon tunnel 249
  - Chabot tunnel 249
  - Crystal Springs by-pass 298
  - Dry Creek tunnel 248
  - Early intake works 284
  - Groveland tunnel....249, 283, 284
  - Hetch Hetchy aqueduct tunnels 246-249
  - Hetch Hetchy dam foundations 287
  - Huntley tunnel 250
  - Irvington gate house 255
  - Klamath project tunnels 250
  - Lincoln mine tunnels 250
  - Los Angeles aqueduct tunnels 224, 225
  - Los Angeles pipe 230, 234
  - Mission Pass tunnel 254
  - Moccasin Peak tunnel 248
  - Orphan Asylum tunnel 251
  - Potrero tunnel 251
  - Redwood tunnel....244, 246, 253
  - Salt River project tunnels 250
  - San Antonio tunnel 258
  - San Bruno tunnel 295
  - San Leandro dam enlargement 134
  - San Lorenzo Creek siphon 291
  - Santa Ana Canal tunnels 250
  - Southern Pacific bay shore tunnels 251
  - Southern Pacific Sierra tunnels 250
  - Tesla tunnel....244, 247, 283
  - Tuolumne River canyon crossing 279
  - Valle tunnel 247
  - Western Pacific Railroad tunnels 251
  - Yakima project tunnel 250
- Excavation required, Hetch Hetchy dam 118, 287

INDEX

Page

- Excellence of foundations, Hetch Hetchy dam site 287
- Excelsior Homestead District—
  - Inadequacy of water supply 220
  - No mains for fire protection 220
- Excessive irrigation—
  - Creates lakes, pools and swamps in Modesto and Turlock Districts 358
  - Injuring large areas in Modesto and Turlock Districts 358
- Excessive storage required for water supply in bay region 383
- Excessive use of water—
  - By Modesto and Turlock Irrigation Districts 83, 358
  - For irrigation 357
  - Statements of residents, Modesto and Turlock Districts 358
- Exchange of lands with U. S. Government 152
- Exclusion—
  - Of campers 52
  - Of campers and tourists, Boston water supply 35
  - Of picnickers 35
  - Of public, Boston reservoirs 35
  - Of tourists and campers from Hetch Hetchy absurd 33, 52
- Excrement, depositing of 34
- Expansion of San Francisco stopped through lack of water 80
- Expenditures—
  - By San Francisco on Hetch Hetchy project 72
  - By San Francisco on Hetch Hetchy project, reimbursement by D. P. Doak 328, 329
  - Incurring of by San Francisco on road construction 72
- Expenses—
  - People's Water Co., 1911 177
  - Spring Valley Water Co. 385
- Expensiveness of investigations 75
- Experiments on evaporation, high altitudes 199
- Experimental farm, Niles Cone 204
- Experts engaged on investigations 81, 82
- Exploitation—
  - Eel River 345
  - Feather River 347, 348
  - McCloud River 335, 336
  - Mokelumne River 365
  - Stanislaus River 305
  - Tuolumne River 82, 83, 106, 107
- Exploration by diamond drilling 122
- Exposure, mountain water, to smallest possible extent 129
- Extended development of local sources 71
- Extension of mains, San Francisco—
  - Necessity to remedy inadequate water service 64, 211-220
  - Refusal of Spring Valley Water Co. to make extensions 213, 214
- Exterior of steel pipe, protection of 229, 230
- External seepage pressure, Hetch Hetchy aqueduct tunnels 221

- Facilitating construction through circular cross section 221
- Factor of safety through storage 349
- Factory population, San Francisco 77
- Failure, Lyons Ranch dam 304, 305
- Fairmount District—
  - Complaints of inadequate water service 211, 217
  - Inadequate water pressure 217
  - Lack of fire protection 211
  - Size of mains 217
  - Views of 217
- Fairview Terrace, no mains for fire protection 219
- Fall—
  - Canyon division, Hetch Hetchy, by series of cascades 286
  - Eel River 345, 346
  - Feather River dam to San Francisco 350
  - Ground water below sea level 176
  - Hetch Hetchy dam 118
  - Knight's Ferry 307, 308
  - McCloud River 327, 336
- Falls Creek—
  - Area of watershed 374
  - Line of flow 117
  - Tables of run-off 375, 376
- Falls, Hetch Hetchy Valley 11, 16

Page

- Fall, utilization for power—
  - Hetch Hetchy project 29, 31, 139, 141, 143
  - Under Freeman plan 139
  - Under Grunsky plan 139, 140, 141
  - Under Manson plan 139, 143
- Famine, water 65
- Farmers, Niles Cone—
  - Controversies with 91
  - Opposition to complete diversion of flow 189, 190
  - Opposition to impounding of flood waters 68
  - Rights of 179, 187
- Farming lands—
  - Boston water supply catchment areas 36
  - Niles Cone 203
  - Stanislaus River watershed 303
- Fault—
  - Corral Hollow 264
  - Hetch Hetchy aqueduct 110, 111, 264
- Fault lines, San Francisco 321
- Fault zones, Hetch Hetchy aqueduct 109
- Favorable conditions—
  - Elizabeth tunnel 226
  - Hetch Hetchy aqueduct tunnels 221, 223
  - Oakdale District irrigation tunnels 221, 223
  - San Joaquin Valley pipe line 231
- Feasibility of Hetch Hetchy aqueduct 71
- Feather River—
  - Adequacy of supply 349
  - Coloration of water 347
  - Discharge 348, 349
  - Diversion dam 350
  - Diversion point 347
  - Diversions 348
  - Flow 348
  - Gravity filtration project 349-353
  - Minimum flow 348, 349
  - Power development 199
  - Pumping and detention project 350, 353
  - Purification by filtration 349
  - Purification by storage 349
  - Run-off 348
  - Stream flow 348
  - Swollen from heavy rains 347
  - Treatment of water 348
  - Turbidity of water 347
  - Water power development 100
- Feather River Canal Co.—
  - Canal constructed by 348
  - Proposed diversion by 348
- Feather River conduit, cost of 351, 352
- Feather River dam—
  - Cost of 350
  - Height 350
  - Wages paid on 251
- Feather River, North Fork—
  - Discharge 348, 349
  - Fed by group of springs 347
  - Practically whole drainage basin in national forest reserve 347
  - Summer flow 347
  - Will be developed under government restrictions 347
- Feather River project—
  - Bay crossing 352
  - Capitalized cost of operation 353
  - Comparison with Sacramento River project 347
  - Comparative cost of pumping and gravity propositions 353
  - Conduit 351, 352
  - Cost of water delivered in San Francisco 353
  - Disadvantages of 157, 160j
  - Equalizing reservoir in Fruitvale 352
  - Filter plant operation 352, 353
  - Incidental costs 352
  - Martinez-Oakland tunnel 352
  - Operation cost 352, 353
  - Report on by C. E. Grunsky 347-354

Page

- Feather River project—
  - Sanitary precaution by storage 350
- Feather River water—
  - Treatment 348
  - Turbidity 347
- Feather River watershed—
  - Climate 348
  - Grazing areas 347
  - Lumber camps 347
  - Stock-raising 347
  - Timbered areas 347
- Federal—
  - Control of sanitary regulations, Hetch Hetchy water supply 34
  - Ownership in Hetch Hetchy Valley 13
  - Supervision of Hetch Hetchy Valley to prevent defilement of water 13
- Federation, communities, San Francisco Bay, under borough system of government 165
- Fencing, San Joaquin Valley, cost of 270
- Fertility—
  - Livermore Valley 187
  - Mokelumne River region 365
  - Niles Cone 187
  - Swamp lands 77
- Field engineering—
  - Hetch Hetchy project 299
  - Los Angeles aqueduct 299
  - New York water supply 299
- Field offices, Hetch Hetchy 286
- Field shops—
  - Bay Head pipe 236
  - Hetch Hetchy pipe line 231
- Filing of report of John R. Freeman 5
- Filling of pore spaces, Livermore Valley gravels 201
- Filtered river water harder than Tuolumne water 56
- Filtered water supply—
  - Alternative routes 322
  - Antioch pumping station 320
  - Balancing reservoir 320
  - Bay crossing 320, 321
  - Cost of operation 325
  - Emergency intake 319
  - Estimates of cost 324, 325
  - Filters 320
  - Incidental cost 325
  - Intake 318
  - Lands required for 325
  - Length of pipe line 319
  - Map showing routes 318
  - Monte Diablo route 319-322
  - Oakland reservoir 320
  - Pipe line routes 318
  - Protection against accident 320
  - Rights of way required 325
  - Pumping stations 318
  - Report by Allen Hazen 315-325
  - River crossings 320
  - San Francisco pumping station 321
  - Steel pipe 320
  - Tunnel, Monte Diablo route 320
  - Tunnel routes 318
  - Tunnel under bay 321
- Filtering turbid water clogs the pores 88
- Filter plant operation, Feather River project 352, 353
- Filter plants—
  - Feather River project 352
  - Filtered water supply project 318
  - People's Water Co. 177
  - Sacramento River project 319
  - San Joaquin River project 319
- Filters—
  - Sacramento River project 320
  - San Joaquin River project 320

Page

- Filtration—
  - By coagulents 317
  - By sand 34
  - Calaveras water 61
  - Desirable to improve physical qualities of water 54
  - Feather River 349
  - McCloud River water 334
  - Not necessary, of stored waters open to public 48, 54
  - Of effluents, Hetch Hetchy Valley 34
  - Sacramento River water 57, 317
  - Sand 34
  - Sanitary necessity for 158
  - San Joaquin River water 317
  - Spring Valley water 61
  - Stanislaus River water 309
  - Surface supplies from Peninsula 61
  - Through coarse sand 34
  - Tuolumne River water 56
- Filtration tunnels, Antioch 228
- Fire Department, San Francisco—
  - Reports on inadequate fire protection 211, 218, 219
  - Reports on inadequate water pressure 218, 219
- Fire hydrants, San Francisco, water pressure 215, 218, 219
- Fire protection—
  - Lack of in Bernal Heights District 211
  - Lack of in Buena Vista District 211, 215, 216
  - Lack of in Fairmount District 211
  - No mains for on certain streets, San Francisco 219, 220
  - San Francisco, lack of 211
- Fisher, Hon. Walter A.—
  - Interview with 7
  - Order by 7
- Fishing—
  - McCloud River 336
  - Tributary streams, Tuolumne River 36
  - Up-stream parts of reservoirs, Hetch Hetchy project 36
- Fitchburg wells—
  - Proportional yield from 172
  - Yield 177
- Fitzgerald, D., on partial emptiness of reservoirs 187
- Fixing of rates—
  - Oakland 177
  - Water districts 170
- Flats, Stanislaus River 303, 304
- Flattening pipe, prevention of 229
- Flexible joint pipe, cost of 322
- Flint Tract, no mains for fire protection 219
- Flooding Hetch Hetchy Valley would eliminate mosquitoes produced in swamps there 56
- Flood level, Alameda Creek 181
- Floodwaters—
  - Alameda Creek 85, 86, 180, 181, 193, 198
  - Alameda Creek, conservation of 84
  - Alameda Creek, measurement of 181, 185
  - Alameda Creek, unabsorbed portion of 198
  - Averaging of 199
  - Cherry Creek 98, 143
  - Coyote River 206, 207, 208, 209
  - Hetch Hetchy 98
  - Hetch Hetchy, caught at Poopenaut dam 293
  - Niles Canyon 83, 179
  - Niles dam 181
  - Relation to rainfall 87
  - Reservoirs for impounding 25, 27
  - San Leandro Creek 97
  - Tuolumne River 58
  - Turbidity 200
- Flood wave rising to peaks 200
- Floor, Hetch Hetchy Valley—
  - Elevations 11
  - Ownership of 13
- Flow—
  - Alameda Creek 83, 84, 87, 94
  - Alameda Creek, Lippincott on 85
  - Alameda Creek, recorded too large 82, 84

Page

- Flow—
  - Big Bend 349
  - Cherry River 98-99, 101-103
  - Constancy of 31
  - Coyote River 206, 207
  - Diminution in 205
  - Eleanor Lake 98-99, 101-103
  - Feather River 348
  - Hetch Hetchy 101-103
  - Hetch Hetchy dam site 98, 99
  - La Grange 100-103
  - Laguna Creek 86
  - McCloud River 329, 331, 339, 340
  - Niles Canyon 83, 84, 179
  - Niles Canyon, wide range of 83
  - Recording of 33
  - Sacramento River 317
  - San Joaquin River 317
  - Stanislaus River 307
  - Stanislaus River, Middle Fork 303, 304
  - Stanislaus River, North Fork 303, 304
  - Stanislaus River, South Fork 303, 304
  - Tuolumne River 98-99, 101-103
  - Underground waters, Alameda Creek, constancy of 197
  - Vernon Lake 16
- Flowing artesian wells 206
- Flow line—
  - Arroyo del Hambre reservoirs 349
  - Cherry Valley reservoir 26
  - Crystal Springs reservoir 294
  - Eleanor reservoir 27
  - Hetch Hetchy reservoir 11
  - San Andreas reservoir 294
  - San Antonio reservoir 256
- Flow of water through Coyote Valley gravels 207
- Flow over dams, Alameda Creek 181
- Fluctuations—
  - Daily draft 294
  - Plane of saturation 198
  - Run-off, Alameda Creek 190
  - Stream flow 188
  - Water table 358
- Flume—
  - Early intake 284
  - Hetch Hetchy dam 287
  - Sierra and San Francisco Power Co 305
- Food supply, lowering in cost of, through utilization of all of Tuolumne waters 144
- Foothill growth, Stanislaus River watershed 303
- Foothill region, Stanislaus River 303
- Foothill storage—
  - In Colorado 58
  - Stanislaus River 307
  - Undesirable for city supply 304, 307
- Forage for teams, Hetch Hetchy aqueduct 231
- Forbidding of bathing in reservoirs 34
- Forebay—
  - Early Intake 284
  - Moccasin Creek powerhouse 280
- Foremen's wages, Los Angeles aqueduct tunnels 223
- Forest growth—
  - Eleanor watershed 53
  - Hetch Hetchy region 59, 60
  - Hetch Hetchy watershed 53
  - McCloud River watershed 329, 336
  - Stanislaus River watershed 303
  - Upper Tuolumne region 53
- Formation—
  - Of a metropolitan water district, San Francisco Bay region 63, 64
  - Of cones 174
  - Of lakes in districts through excessive irrigation 358
- Formations—
  - Antonio-Valle division 259, 260
  - Branner, J. C., on 110, 111, 124

Page

- Formations—
  - Buriburi tunnel 296
  - Canyon tunnel 249, 284
  - Chabot alternative aqueduct 124
  - Chabot tunnel 249, 291
  - Dry Creek tunnel 248, 276, 278
  - Groveland tunnel 249, 283
  - Hetch Hetchy aqueduct line 259, 260, 264
  - Hetch Hetchy aqueduct tunnels 223
  - Los Angeles aqueduct 225, 226
  - Mission Pass tunnel 246, 255
  - Moccasin Peak tunnel 248, 279
  - Peninsula alternative aqueduct 124
  - Redwood tunnel 244, 246, 252, 253
  - San Antonio tunnel 246, 258
  - San Bruno tunnel 295
  - Tesla tunnel 244, 247, 264, 265, 283
  - Valle tunnel 247, 259, 260, 265
- Forms for concrete—
  - Cost of making 243
  - Hetch Hetchy aqueduct 242, 243
  - Hetch Hetchy dam 288
- Formula—
  - Spring Valley Water Co. for computing Alameda Creek discharge 180
  - Water-carrying capacity of Hetch Hetchy aqueduct tunnels 221
- Fort Collins, Colo., foothill reservoirs near 58
- Foundation preparation—
  - Hetch Hetchy dam 287
  - Poopenaut dam 291
- Franchise, water supply, San Francisco—
  - Ensign, George H. 386
  - Merrifield, A. D. 386
  - Mountain Lake Water Co. 385
  - San Francisco City Water Works 386
  - Spring Valley Water Co. 393
- Franciscan formation—
  - Branner, J. C., on 110, 111, 124
  - Chabot alternative aqueduct 124
  - Peninsula alternative aqueduct 124
  - Percentage of timbering of tunnels through 259, 260, 265
  - Potrero tunnel 296
  - Tesla tunnel 246, 264
  - Valle tunnel 247, 259, 260
- Francisco street reservoir—
  - Elevation 131, 387
  - Location of 131
  - Storage capacity 131, 387
- Freedom—
  - From accidents, New York aqueduct 71
  - From contamination, McCloud River 329
  - From mineral matter, Sacramento River water 317
- Freeman, John R.—
  - Consulting engineer, New York water supply 138
  - Curve on rainfall 199
  - Endorsement of proposal to purchase Spring Valley Water plant 401
  - Engineering reconnaissance by 71
  - Geological study by 71
  - Investigations by 75
  - Member, Board of Engineers, Los Angeles aqueduct 138, 223
  - Member, Metropolitan Water Board, Boston 138
  - Obligation of city to 5
  - On increase of population 76
  - Report by on Hetch Hetchy project 5
  - Statement on McCloud River project 342-344
  - Studies and experience of 138
  - Viewpoint on Hetch Hetchy project 138
- Freeman plan of development—
  - Advantages over former plans 142
  - Capacity of 139, 140
  - Comparison with Grunsky and Manson plans 139, 140
  - Declivity adopted 141
  - Elimination of open canals 142

Page

Freeman plan of development—
  Elimination of pumping ... 142
  Elimination of trestles ... 142
  Horsepower available ... 141
  No pumping ... 142
  Pipe lines ... 139, 141
  Power development ... 141
  Power houses ... 139, 141
  Preference for pressure tunnels ... 138
  Provision for metropolitan water district ... 140
  Quantity available daily under ... 139, 140
  Safety against accident ... 144
  San Joaquin Valley crossing ... 139
  Siphons ... 139, 140
  Tunnels ... 139, 140
Free water supplied by Spring Valley to San Mateo Water Works ... 388
Freight rates—
  Cement ... 241, 242
  Dove Creek pipe line ... 230
  Hetch Hetchy pipe ... 231
  Reduction in, through Panama Canal ... 231
  San Antonio pipe line ... 230
Freshets—
  Coyote River ... 206
  McCloud River ... 334
  San Joaquin River ... 269
Friction joints—
  Hetch Hetchy pipe ... 232
  Spring Valley pipe ... 232
Fruits, shipping of ... 77
Fruitvale reservoir—
  Cost of ... 352
  Equalization of flow ... 350
Fuel oil, cheapness in California ... 324
Full capacity, tunnels, Hetch Hetchy aqueduct, from start ... 300
Further—
  Immediate work on Hetch Hetchy aqueduct necessary ... 71
  Investigation necessary ... 70
  Storage and diversion of underground waters, Niles Cone ... 70
Future—
  Dam, Hetch Hetchy ... 285
  Development of intensive farming ... 187
  Growth, bay cities ... 123
  Needs, bay region, quantity of water required for ... 81
  Requirements, bay cities ... 65, 67
  Reserves against accident ... 65, 67
  Safety of bay cities requires reservation of unappropriated waters of Tuolumne River ... 22
  Water supply, planning of ... 189
Future population—
  Alameda County ... 78
  Contra Costa County ... 78
  Greater San Francisco ... 77
  San Francisco ... 78
  San Mateo County ... 78
  Santa Clara County ... 78

Galloway, J. D.—
  Appointment as engineer by Berkeley City Council ... 161
  Appointment as engineer by Oakland City Council ... 162
Gardens, water for ... 79
Garfield permit—
  Based on Grunsky studies ... 144
  Conformed to in Manson 1911 plan ... 143
  Date of ... 138
  Form of ... 149
  Misunderstandings causing terms of ... 151
  Not broad enough for present needs ... 140, 150
  Outgrown ... 144, 150
  Plan of development under ... 138
  Stipulations in ... 149, 150
Gate house—
  Crystal Springs reservoir ... 252
  Eleanor dam ... 289

Page

Gate house—
  Irvington ... 123
  Islais Creek Valley junction ... 295
  San Andreas junction ... 297
  San Antonio ... 258, 259
  San Joaquin River crossing ... 270
Gate houses—
  Basis of estimates on ... 251
  Eleanor-Cherry tunnel ... 25
Gates—
  Cherry Valley dam ... 289
  Eleanor dam ... 289
  Hetch Hetchy dam ... 118, 121, 285, 288
  Irvington gate house ... 255
  Poopenaut dam ... 291
  San Andreas junction ... 297
  San Joaquin pipe line ... 269
  San Joaquin siphon ... 276
Gate tower, Cherry Valley dam ... 289
Gaugings—
  Laguna Creek ... 193
  McCloud River ... 329, 334, 339, 340
  Pescadero Creek ... 96
  San Antonio Creek ... 193
  San Gregorio Creek ... 96
  South Yuba River ... 101
  Tuolumne River ... 101-3
  Yuba River ... 101, 355
Gauging weirs ... 33
Generation of power—
  Stanislaus River ... 305
  Tuolumne River ... 282
Geologic folios ... 109, 110
Geologic history, Livermore Valley ... 200
Geological formations—
  Antonio-Valle division ... 259, 260
  Branner, J. C., on ... 110, 111, 124, 200
  Chabot alternative aqueduct ... 124
  Chabot tunnel ... 249, 291
  Dry Creek tunnel ... 248, 276, 278
  Groveland tunnel ... 283
  Hetch Hetchy aqueduct tunnels ... 243, 246, 249, 252, ... 253, 255, 258, 264, 265, 276, 278, 279
  Livermore Valley ... 84, 86, 200, 259
  McCloud River ... 333, 334
  Mission Pass tunnel ... 246, 255
  Moccasin Peak tunnel ... 248, 279
  Peninsula alternative aqueduct ... 124
  Redwood tunnel ... 252, 253
  San Antonio tunnel ... 246, 258
  Tesla tunnel ... 247, 264, 265
  Valle tunnel ... 247, 259, 260
Geological reconnaissance ... 109, 110
Geological sections—
  Hetch Hetchy alternative distribution aqueducts ... 125
  Hetch Hetchy aqueduct ... 110, 112, 117
  Livermore Valley ... 86
Geological studies—
  By Freeman ... 71
  Hetch Hetchy aqueduct tunnels ... 110, 111
  New York aqueduct ... 71
Geology—
  Bay shore ... 91
  Livermore Valley ... 84
  McCloud River watershed ... 333, 334
Geometric progression, growth of cities ... 77
Germs—
  Destroyed by storage ... 37
  Die in storage reservoir ... 32
  Water-borne ... 37, 42
Glacial formation—
  Big Dam reservoir ... 304
  Hetch Hetchy dam site ... 287
  Stanislaus River watershed ... 303

Page

- Glasgow water supply—
  - Aqueduct length 48
  - From Loch Katrine 48
  - Sanitary restrictions 33
  - Tourists visiting catchment area 48
  - Unfiltered water 48
- Glencoe supplied from Clark ditch 369
- Glen Park Terrace, no mains for fire protection 219
- Glutz, J. B., San Francisco, complaint on inadequate water supply 213
- Gneissoid granite, Elizabeth tunnel 226
- Goat Island route, filtered water supply 318, 322
- Golden Gate—
  - Depth of water 321
  - Tunnel under 345
- Gorge—
  - Hetch Hetchy 8
  - Santa Clara Valley 206, 207
- Government lands, Poopenaut Valley 292
- Grades—
  - Groveland tunnel 283
  - Hydraulic 113, 117
  - Most favorable 72
  - New roads 281
  - Priest's Hill 289
  - Road, Chinese Camp to Hog Ranch 289
  - Road, Rosasco to Hetch Hetchy 290
  - Roads into Hetch Hetchy region 13, 72
  - Scenic road, Hetch Hetchy 15
  - Wagon road to Hetch Hetchy 13
  - Wood's Creek 289
- Grading—
  - Contract prices 251
  - Guadalupe Valley pipe line 296
  - Millbrae-San Antonio division 297
  - Unit prices 251
- Granite areas—
  - Eleanor watershed 53
  - Hetch Hetchy watershed 53
  - Upper Tuolumne region 53
- Granitic formation—
  - Big Dam reservoir 304
  - Branner, J. C., on 111
  - Canyon tunnel 284
  - Elizabeth tunnel 226
  - Groveland tunnel 249, 283
  - Hetch Hetchy aqueduct 116, 117
  - Los Angeles aqueduct tunnels 225
  - Poopenaut dam 293
  - Stanislaus River watershed 303
  - Strawberry Creek 304
  - Tesla tunnel 283
- Granodiorite—
  - Canyon tunnel 249, 284
  - Groveland tunnel 283
- Grants of public lands for roads 129
- Grapevine division, Los Angeles aqueduct 224, 227
- Gravel bars, Alameda Creek 183
- Gravel conduit—
  - Clogging by silt 200
  - Plugging up of 200
- Gravel deposits—
  - Alameda Creek 197
  - Avoidance of tunneling through 259
  - Coyote Valley, immense quantities of water sinking into 207
  - Impossibility of increase of storage in future 190
  - Kidneys in 198, 199
  - Livermore Valley 89, 90, 190, 191
  - Livermore Valley, voids in 199
  - Pleasanton, storage capacity 190
  - Santa Clara Valley, vastness of 207, 208
- Gravel from public lands for construction work 15, 22
- Gravel intakes, absorptive power of 196
- Gravelly Valley—
  - Area in watershed of Eel River commanded by 345

Page

- Gravelly Valley—
  - Height of dam 345
  - Storage capacity of reservoir site 345
- Gravel out-crops, Alameda Creek 198
- Gravels—
  - Inflow of water into 201
  - Interstices in 201
  - Irregular pockets 88
  - Silting of 191
  - Velocity of movement of 198
- Gravel storage, Coyote River 206
- Gravel strata—
  - Coyote River 206, 207
  - Underlying Miller Ranch 206
  - Underlying Santa Clara Valley 206
- Gravity conduit, McCloud River project, cost of 337
- Gravity delivery to San Francisco, Yuba River project 356
- Gravity filtration project, Feather River 349-353
- Gravity flow—
  - Advantages of 153
  - American-Cosumnes project 310, 311
  - Bay Head pipe 236
  - Hetch Hetchy to Chabot Lake 134
  - Hetch Hetchy to Irvington 20
  - Hetch Hetchy water to San Miguel 129
  - Mokelumne River 160d
  - Peninsula system 383
  - San Antonio reservoir to San Francisco 122
  - Sunol and Pleasanton water into Crystal Springs reservoir 122
  - Water without pumping advisable for San Francisco 124
- Gravity supplies the most satisfactory 57
- Gray Rocks tunnel—
  - Cost 337
  - On Mt. Shasta aqueduct, McCloud River project 332
- Grazing areas—
  - Feather River watershed 347
  - McCloud River watershed 336
- Great and sudden floods, Alameda Creek 87
- Greater Oakland—
  - Consumption per capita 79
  - Group of cities forming 63
  - Increase of population 76
  - Joining in metropolitan water district 65
  - Prospects for future growth of 123
- Greater San Francisco—
  - Actual rate of growth 76
  - Estimated growth of 76
  - Estimates on population 77
  - Valleys tributary to 77
  - Water district for 91
- Greater San Francisco Association—
  - Purpose of 165
  - Representatives from bay cities to 165
  - Signatures obtained to petition for constitutional amendment on consolidation of bay cities 165
- Greater San Francisco movement—
  - Initiated by Greater San Francisco Association 165
  - Origin of 165
  - Petition signed in support of 165
  - Sentiment strong in favor of 166
- Greater water supply, Oakland—
  - Capacity of 175, 176
  - Reservoir sites 175, 176
- Greater water supply, People's Water Company 175, 176
- Great fire, San Francisco 76, 77, 78
- Great storage from gravel beds impracticable 86
- Great Western Power Company—
  - Building Big Meadows dam 348
  - Power development on Feather River 100
  - Wages paid for common labor 251
- Greeley, Colo., foothill reservoirs near 58
- Grossman, M. L., San Francisco, complaint of inadequate water supply 213
- Ground contours, Niles Cone 95

Page

Ground waters—
- Alameda Creek, litigation over 91
- Average quantity used daily, East Bay region 176, 177
- Diversion of water for outside use 205
- East Bay region, 173
- Fall of below sea level 175, 176
- Bay Shore gravels, increased use of 81
- Bay Shore, source of 91
- Brooklyn, overpumping of 80
- Industrial use of 176
- Irrigation demands on 80
- Legal difficulties 175
- Manufacturing demands on 80
- Modesto and Turlock Districts 358
- Overpumping of, Brooklyn 70
- Overpumping of, Niles Cone 70
- Peninsula 81
- Proportion of total water supply to East Bay region 172
- San Francisco Bay shore 80
- Supreme Court decisions 97, 175

Ground waters, Niles Cone—
- Claims adverse to water company 69
- Depletion of 91
- Further storage and diversion of 70
- Height of 91
- Overpumping of 80

Ground waters, Pleasanton—
- Claims adverse to water company 69
- Quality of 61

Ground waters, Sunol, quality of 61

Grouse Valley 160a

Groveland, road from Chinese Camp 289

Groveland tunnel—
- Cost of 283, 284
- Depth below surface 283, 284
- Diameter 249, 283
- Formations 249, 283
- Grades 283
- Length 283
- Percentage timbered 249, 283
- Shafts 284
- Unit costs 249, 283, 284

Growing use of Niles Cone ground water 92, 93

Growth—
- Algae, foothill region, Stanislaus River 304
- Cities, geometric progression 77
- Los Angeles 78
- Organic, foothill region, Stanislaus River 304
- Phenomenal, Pacific Coast cities 78
- Stoppage, San Francisco, through shortness of water 80
- Vancouver 78
- Weeds on exposed beds of reservoirs 187

Grunsky, C. E.—
- Alameda Creek discharge 82
- Canal locations by 108
- Eel River, report on 345, 346
- Feather River, report on 347-354
- McCloud River project, memorandum on 331-333
- McCloud River project, notes on 333-8
- McCloud River water rights, letter to City Attorney on 338-41
- Mokelumne River project, conclusions on 371
- Ocean slope creeks 81
- Pipe line locations by 108
- Stanislaus River project, report on 303-9
- Surveys by 108
- Yuba River, report on 365, 366

Grunsky plan of development—
- Bridges 139
- Canals 139-41
- Capacity of tunnels 140
- Comparison with Manson and Freeman plans 139, 140
- Criticisms of 140-2, 144
- Crossing of San Joaquin Valley 139, 141
- Economies in construction 142
- Horse power available 141

Page

Grunsky plan of development—
- Open canals 139, 140
- Pipe lines 139, 140
- Power development 140, 141
- Power houses 139, 140, 141
- Power used for pumping 141
- Quantity of water available daily under 139, 140
- Siphons 139-41
- Smallness of capacity of project 142
- Transmission of power 141
- Tunnels 139-41
- Using of natural channels 140, 142
- Weak points 142, 144

Guadalupe tunnel—
- Connections with 296
- Cost 296
- Percentage timbered 296

Guadalupe Valley pipe line—
- Cost of 296
- Grading 296
- Unit costs 296

Haight and Ashbury Improvement Association, San Francisco, complaint, inadequate water supply 215

Hale dam 306

Hale reservoir, storage capacity 306

Hale's Mill 304

Half Moon Bay—
- Communities on 96
- Public wagon road to, crosses Crystal Springs reservoir 33

Hall, William Ham—
- Proposed development of water power and reservoirs 108
- Surveys by 108

Hamilton, Mount—
- Bay Cities Water Company's properties on slope of 96
- Creeks on slope of 96, 186
- Rainfall 87, 193, 194, 195, 199
- Source of Coyote River on slope of 206
- Source of supply of Bay Cities Water Company 96
- Source of supply of United Properties Company 96
- Streams rising south of 206
- Vapor-laden winds 88

Hamilton, R. L., San Francisco, complaint, inadequacy of water supply 214

Hammatt, W. C.—
- Reconnaissance of Hetch Hetchy scenic road 290
- Surveys by 109

Harbor Board, price paid for cement 241

Harbor, San Francisco 78

Harden Ranch, location of 117

Hardness—
- Alameda Creek water 61, 194, 198
- Of filtered river water 56
- Of ground waters, Pleasanton 61
- Of ground waters, Sunol 61
- Of Sacramento River water 316, 317
- Of San Joaquin River water 317
- Of Spring Valley water 62, 69, 138
- Of Tuolumne water 316, 317
- Value of in a public water supply 317

Haulage—
- Bay Head pipe line 231
- Building materials, Hetch Hetchy project 72
- Hetch Hetchy pipe, equipment for 231
- Los Angeles aqueduct steel pipe 230, 231
- Los Angeles aqueduct tunnels 226

Haulage costs—
- Hetch Hetchy aqueduct 231
- Los Angeles aqueduct pipe 230, 231
- San Joaquin Valley pipe 231

Haul, average, Hetch Hetchy aqueduct 231

Haul, lengths of—
- Hetch Hetchy aqueduct 289
- Los Angeles aqueduct 231

INDEX

Page

Hayward—
  Draft on Niles Cone 175
  Number of services in 178
  Prospects for future growth of 123
  Supplied by San Lorenzo Water Company 178
Hayward Cone—
  Collection of water by pumping from areas not naturally appurtenant to wells 91
  Limit of available draft 173, 175
  Replenishment of 173, 175
Hazen, Allen—
  Estimate on filters at Antioch 228
  Report by on filtered water supply 53, 57, 315-25
Head—
  Alameda Creek crossing 258
  Bay Head pipe 236
  McCloud River project pumping stations 337
  Mission Pass channel 255
Headquarters, engineering—
  Hetch Hetchy project 299
  New York water supply 299
Headquarters' expense—
  Hetch Hetchy aqueduct divisions 300-1
Head water elevation—
  Arroyo Mocho 201
  Arroyo Valle 201
Headworks—
  Early intake 284
  Stanislaus River, joint construction by South San Joaquin and Oakdale irrigation districts 307
Heavy plant cost—
  Hetch Hetchy aqueduct divisions 300-301
  Omitted from estimates, Hetch Hetchy aqueduct 240
Heavy plant depreciation, Hetch Hetchy aqueduct 298
Helvellyn, Mount 47
Hemlock, Lake 53
Hercules Water Company—
  Daily supply by 174
  Number of services 177
  Population supplied by 177
  Pumping station 178
  Reservoir 177
  Supplies Pinole 177
  Wells 178
Hermit Valley—
  Area of reservoir 160a
  Dam 160a
  Storage capacity, reservoir 160a
Hering, Rudolph, report on Alameda Creek ground waters 187
Herring Creek 303, 304
Hetch Hetchy—
  Absurdity of literature issued against by People's Water Company 160j
  Best mountain source for San Francisco district 75
  Cost of cement delivered at 242
  Development should precede work on Eleanor or Cherry 154
  Discharge 101-103
  Distance from Hog Ranch 289
  Distance from Poopenaut Valley 293
  Diversion from Eleanor Lake and Cherry Creek 25
  Geological conditions 221
  Gravity flow from 20
  Hotel site 11, 60
  Inaccessibility of 147
  Mechanical shop buildings 287
  Present neglect 151
  Railroad from Rosasco 290
  Rain gauge elevation 105
  Real value of 151
  Reasons why Hetch Hetchy should be developed first 154
  Road from Rosasco 290
  Sanitary survey 53-55
  Sierra Club excursion to 60
  Superior to all other sources in quality of water 151

Page

Hetch Hetchy
  Temporary buildings 286
  Time advisable to begin development of 179
  Unpopulated watershed 344
  Wagon road to 13, 15
Hetch Hetchy aqueduct—
  Accessibility 289
  Allowance for overhead charges 298
  Arguments for and against maximum development at present 145, 146
  Average length of haul 231
  Bad spots 111
  Basis of estimate on 239, 240
  Branches from 123, 124
  Branches from to various cities 20
  Capacity of 20, 21
  Capacity diagrams 222
  Character of rocks for tunneling 111, 264
  Comparison with Los Angeles aqueduct 128, 226, 227
  Conditions of operation 230
  Connection with city distributing system 20
  Cost lessened by steep gradients 155
  Daily delivery of 21
  Delivery into storage reservoirs or city distributing system 20
  Depreciation on heavy plant 298
  Description of 15, 20
  Designed to connect up with Spring Valley distribution system 63
  Division No. 1 .... 240, 294-297
  Division No. 2 .... 240, 297
  Division No. 3 .... 240, 241, 297, 298
  Division No. 4 .... 241, 252-254
  Division No. 5 .... 241, 254-258
  Division No. 6 .... 241, 258, 259
  Division No. 7 .... 241, 259, 260
  Division No. 8 .... 241, 260-281
  Division No. 9 .... 241, 281-284
  Division No. 10 .... 241, 284-286
  Division No. 11 .... 241, 286-288
  Division No. 12 .... 289, 290
  Division No. 13 290
  Division No. 14 290
  Division No. 15 .... 290, 291
  Division No. 16 291-293
  Divisions of 240, 241
  Effect on cost of abnormal rate of wages 240
  Elevations on 112, 117
  Equipment 298
  Equipment cost 270
  Estimates 160n-160q
  Fault lines crossed by 110, 111
  Feasibility of 71
  Gate house on 20
  Haulage unit 231
  Immediate further work necessary 71
  Incidental costs 240
  Length of 128
  Length of haul 289
  Lining, adverse conditions 223
  Loading applied to estimates 160p, 160q
  Method followed in making estimates 239, 240
  Natural conditions along 221
  Need not connect with Spring Valley distribution system 62
  Overhead charges 300, 301
  Points of control 109
  Portion out of reach of existing roads 289
  Possible danger from earthquakes 110, 111
  Power development 128
  Power houses on 29, 30
  Power possibilities 29
  Pressure tunnels 120
  Provision for future power development 29
  Rights of way required for 72
  Rocks to be encountered 111

Page

- Hetch Hetchy aqueduct—
  - Route of 20, 112-117
  - Saving in cost of 127
  - Shorter route for 127
  - Siphons 21
  - Storage reservoirs for 20
  - Surplus capacity of 21
  - Time required for building 74
  - Unit costs 246-249
  - Working points within easy reach of railroads 289
- Hetch Hetchy aqueduct line—
  - Borings 264
  - Change in line owing to geological conditions 110, 129, 221, 259, 265
  - Contour levels 261-263, 266-268, 271-275, 277, 280, 282
  - Doubtful ground 221, 223
  - Geological formations 259, 260, 264
  - Intrusion of serpentine 264
  - Sandstone beds 264
  - Sedimentary rocks 259, 264
  - Testings 264
  - Topography 221, 261, 262, 266-268, 271-275, 277, 280, 282
  - Trial location for 267, 268
- Hetch Hetchy aqueduct location—
  - Plans of location 112-117, 277
  - Plan 277
  - Profile of location 271-274, 277
  - Sections of location 112-117
  - Studies for 271-275
- Hetch Hetchy aqueduct tunnels—
  - Area of 222
  - Basis for estimate of capacity and cost 221-238
  - Basis of unit prices 243, 245
  - Capacity full from start 300
  - Character of rock 111, 264
  - Circular cross section 221
  - Comparisons with Los Angeles tunnels 244, 245
  - Concrete lining 221
  - Cost of cement 246-249
  - Cost of concrete 246-249
  - Cost of excavation 246-249
  - Cost of timbered sections 246-249
  - Cost of untimbered sections 246-249
  - Description of 121
  - Diameters of 222, 243, 244, 246-269
  - Discharge, million gallons 222
  - Favorable conditions for 221, 223
  - Geological formations 243
  - Increase in discharge 221, 222
  - Length of 128
  - Natural conditions 223
  - Percentage timbered 244, 246-249
  - Plan of location 277
  - Plan showing location of 273-275
  - Profile of location 273, 274, 277
  - Quantities 120
  - Route of 4
  - Slope of 222
  - Steepness of hydraulic gradients 221
  - Thickness of lining 242
  - Timbering of 221
  - Typical sections for 243-251
  - Unit costs on 243, 251
  - Velocities 221
- Hetch Hetchy camp—
  - Buildings 286
  - Cabins 286
  - Equipment 286
  - Incidental costs 287
  - Loss on boarding house 287
  - Maintenance and repairs 286, 287
  - Policing of 287
  - Profit in commissary 287
  - Sewage disposal 286
  - Telephone connections 286

Page

- Hetch Hetchy dam—
  - Adit 287
  - Advantages in being high 119
  - Beginning of construction 73, 74, 144
  - Bridge over 118
  - Cascade 118
  - Coffer dam 287
  - Concrete work 118, 287, 288
  - Construction of 9
  - Contours 118
  - Contraction joints 118
  - Cost of 287, 288
  - Crest length 286
  - Cross-section 285
  - Deferred portion of construction 286
  - Depth of water stored 285
  - Diligence in work of construction 74
  - Draw-off gates 285
  - Elevations 8, 11, 118, 285
  - Emergency gates 285
  - Excavation required in construction 118
  - Fall at 118
  - Flumes 287
  - Freeman plan 139
  - Future spillway level 285
  - Gates 118, 288
  - Grunsky plan 139
  - Height 8, 9, 58, 119, 285
  - Height necessary 286
  - Initial development 286
  - Landscape architectural treatment 288
  - Local overhead charges 288
  - Manson plan 139
  - Masonry in 287, 288
  - Mass curve 285
  - Nearby gravel deposits for construction of 287
  - Outlet elevations 11, 13
  - Outlet pipes 10, 11
  - Percentage of "plums" 287
  - Plan 118, 285
  - Plant maintenance and repairs 288
  - Problems of 72
  - Proportion of ingredients for concrete 287, 288
  - Quantities 118, 285
  - Quantities, concrete work 287, 288
  - Roadway, along top of 118, 285
  - Section 118, 285
  - Spillcrest 288
  - Spillway level 285
  - Stairway 118
  - Storage at different heights 286
  - Storage capacity 8, 285
  - Temporary works 287
  - Time required for building 73, 74
  - Total cost 288
  - Ultimate development 286
  - Unit costs 287, 288
  - Water control during construction 287
  - Water level 285
  - Width 8
- Hetch Hetchy dam site—
  - Advantages of 119
  - Borings at 119, 287
  - Discharge at 373
  - Drain holes 287
  - Excellence of foundations 287
  - Gaugings at 98, 99
  - Glacial formation 287
  - Grout holes 287
  - Ideal site 151
  - Little excavation needed 287
  - Location 11
  - Sound granite formation 287
  - Title to 13
  - View of 8

INDEX

Page

- Hetch Hetchy development—
  - Reasons why Hetch Hetchy should be developed first 154
  - Should precede Eleanor or Cherry 154
  - Time advisable to begin 179
- Hetch Hetchy Division—
  - Administration expense 300
  - Construction roads cost 300
  - Description of 241
  - Engineering costs 300
  - Headquarters' expense 300
  - Land purchases 300
  - Right of way purchases 300
  - Total cost 300
  - Transportation of laborers 300
  - Water right costs 300
- Hetch Hetchy gorge—
  - Depth of 287
  - Narrowness of 9, 287
- Hetch Hetchy lands—
  - Joint use for water supply and park 56
  - Ownership by City 138
- Hetch Hetchy pipe—
  - Alternate route 112
  - Area of 222
  - Cost of steel 231
  - Diameters 122, 123
  - Freight cost from East 231
  - Effect on cost of local labor conditions 233
  - Plan showing location 271-275
  - Submerged portion 20
  - Valves on 20
- Hetch Hetchy project—
  - Administration expenses 299
  - Arrangement of estimate 252
  - Assumed base of wages 240
  - Building of roads 240
  - Capacity of initial development 300
  - Changes from original outline 160r
  - City distributing system of Spring Valley not essential to 62
  - Completeness of studies 134
  - Contractors' bond 298
  - Contractors' profit 298, 299
  - Cost of cement 242
  - Covered reservoirs 129
  - Crystal Springs reservoir not essential to 62
  - Division No. 10 not essential in initial development 284
  - Effect on cost of inefficient management 240
  - Employers' liability insurance 298
  - Estimate of cost 160n-160p
  - Field engineering 299
  - Gravity flow to Lake Chabot 134
  - Headquarters, engineering 299
  - Hillside ditches 260
  - Increase in cost for direct delivery to San Miguel 129
  - Investigations to determine cost 71
  - Large scale required for success 142
  - Legal expenses 299
  - Length of construction roads 241
  - Length of scenic roads 241
  - Loading applied to estimates of cost of 160p, 160q
  - Overhead costs 300, 301
  - Probable order and cost of 160L
  - Road building 240, 281, 298
  - Spring Valley distribution system not essential to 62
  - Terminal gate house 252
  - Terminal reservoir 252
  - Trail construction 298
  - Superiority to McCloud River project 344
  - Table showing loading charges included in estimates 160q
  - Transportation of laborers 298
  - Ultimate development 300
  - Wages basis 251
  - Wages, common labor 252
  - When necessary to start construction work 74
- Hetch Hetchy region, working season 73-74

Page

- Hetch Hetchy Reservoir—
  - Area of 286
  - Available inflow 285
  - Catchment area 8, 24
  - Depletion of storage 285
  - Depth to be flooded 6, 12
  - Diversion of waters into from Cherry Creek reservoir and Lake Eleanor 25
  - Drafts upon 11, 13
  - Emptying of 10
  - Flow line 11
  - Freeman plan 139
  - Grunsky plan 139
  - Height of cliffs 6, 12
  - High water 11
  - Inflow 33
  - Low water 11
  - Map of 11
  - Manson plan 139
  - Necessity of developing to full capacity 286
  - Outflow 33
  - Relation depth flooded to height of cliffs 6. 12
  - Releasing of water from 121
  - Replenishment of 11
  - Replenishment from Cherry Creek and Eleanor Lake 25
  - Shores of 13
  - Storage capacity 8. 285
  - Ultimate capacity 286
  - Views 6. 10, 12
  - Water levels 11
  - Watershed tributary to 8. 24
  - Yielding capacity 8. 104
- Hetch Hetchy reservoir site—
  - Area to be cleared 286
  - Cost of clearing 286
  - Map 11
- Hetch Hetchy scenic road—
  - Arcades on 18
  - Branch to Tilltill Valley 290
  - Cost of 290
  - Development of 160r
  - Length of 290
  - Reconnaissance by W. C. Hammatt 290
  - Time for building 74
  - Views 10, 12
- Hetch Hetchy Valley—
  - Advantages to be derived from storing waters in 149
  - As a pleasure ground 145
  - Beauties of 57
  - Below the interesting part (view) 57
  - Cross-sections of 146
  - Floor to be covered by lake 13
  - Floor elevations 11
  - Floor ownership 13
  - Levels run up to 108
  - Map of 11
  - Ownership of 13
  - Present inaccessibility of 148
  - Rain gauges at 101, 105
  - Scenery in 57
  - Sections of 8. 146
  - Small number of visitors to 148
  - Supervision of 13
  - Temporary dam at 73
  - Views 6. 8. 10, 12, 57
  - Widely advertised as pleasure spot 148
- Hetch Hetchy water—
  - Freedom from micro-organisms 36. 138
  - Organic life 36
  - Prevention of defilement 13
  - Purity of 138
  - Softness of 69, 138. 153
- Hetch Hetchy watershed—
  - Area of 8. 24
  - Discharge of flood flow 98

Page

- Hetch Hetchy watershed—
  - Elevation ... 105
  - Forest growth on ... 53
  - Granitic areas in ... 53
  - Insolubility of rock ... 53
  - Mass curve diagram ... 285
  - Rainfall ... 99, 105
  - Run-off ... 10, 97, 101-103, 105
  - Snowfall ... 24, 99, 105
  - Uninhabitable ... 53
  - Yield ... 101-103
- Hetch Hetchy water supply—
  - Management of ... 299
  - Most economical of all Sierra sources ... 151
  - Rights of Oakland to ... 162, 163
  - Water Board for management of ... 299
- High altitudes—
  - Evaporation ... 100, 199
  - Proportion of run-off from precipitation ... 100
  - Temperature ... 199
- High dams not necessary at Eleanor or Cherry ... 104
- High service area, San Francisco ... 212
- High Sierras—
  - Critical period of rainfall ... 99
  - Dry periods ... 99, 100
  - Precipitation ... 99, 100
  - Rainfall ... 99, 100
  - Snowfall ... 99, 100
- High water, Hetch Hetchy reservoir ... 11
- Highland Reservoir—
  - On North Fork, Stanislaus River ... 303
  - Storage capacity ... 306
- Highest use of water ... 21, 22
- Highways around Boston reservoirs ... 35, 36, 37, 38
- Hill service area, San Francisco ... 212
- Hillside ditches, Hetch Hetchy project ... 260
- History of development, water supply, San Francisco ... 386-390
- Hog Ranch—
  - Distance from Hetch Hetchy ... 289
  - Elevation ... 105
  - Location ... 4, 117
  - Nearest accessible point to Hetch Hetchy Valley ... 289
  - Road from Chinese Camp ... 289
  - Road grades ... 289
  - Rainfall ... 105
  - Run-off ... 105
- Holly Park District, San Francisco, inadequacy of water supply ... 220
- Honda Lake—
  - Capacity of ... 131
  - Delivery of Hetch Hetchy water to ... 294
  - District supplied by ... 131, 212
  - Elevation ... 131
  - Increasing capacity of ... 129
  - Storage capacity ... 131
- Hopson, on increase of population ... 76
- Horner's Addition, San Francisco, no mains for fire protection ... 220
- Horsepower—
  - Available for general purposes, American-Cosumnes project ... 311
  - Available under Freeman plan ... 141
  - Available under Grunsky plan ... 141
  - Required for pumping, American-Cosumnes project ... 311
- Hospital maintenance, Hetch Hetchy camp ... 287
- Hotel site, Hetch Hetchy—
  - Admirable site for summer hotel ... 60
  - Drainage from ... 60
  - Location of ... 11
- Hotle project, Yuba River, irrigation of lands ... 348, 355, 356
- Hudson River, crossing of ... 71
- Human activity, McCloud watershed ... 331, 343
- Humidity—
  - Recording of ... 100
  - Rising of ... 100
- Hunt, A. M., plans by ... 143

Page

- Huntley tunnel ... 250
- Hyde, C. G., on discharge of Alameda Creek ... 82
- Hydrants—
  - Parkside, found dry ... 219
  - San Francisco, water pressure ... 215, 218, 219
- Hydraulic capacity, steel pipe ... 121, 122
- Hydraulic elements, tunnels, Hetch Hetchy aqueduct ... 120
- Hydraulic fill—
  - Eleanor temporary dam ... 27
  - San Antonio dam ... 257
- Hydraulic gradients—
  - Coast Range tunnels ... 122
  - Hetch Hetchy aqueduct tunnels ... 113-117, 121, 221, 273-274
  - South Fork Canyon crossing, Tuolumne River project ... 283
- Hydraulic riveting, Hetch Hetchy pipe ... 232
- Hydraulic sluicing—
  - Cherry Valley dam ... 289
  - Eleanor dam ... 289
- Hydro-electric power—
  - Development of ... 29, 31
  - Station, Hetch Hetchy dam ... 30
  - Station, North Mountain ... 143
- Hydrographic conditions, Mokelumne River ... 371
- Hydrographic service, records of flow available to ... 33

- Ideal—
  - Dam site, Hetch Hetchy ... 151
  - Water, Tuolumne River ... 53
  - Watershed, Hetch Hetchy and Lake Eleanor ... 53
  - Weir ... 181, 188
- Ideal conditions—
  - For laying pipe, San Joaquin Valley ... 233
  - Met in Oakdale irrigation tunnels ... 223
- Ideally safe water, Tuolumne River ... 53
- Immediate further work on Hetch Hetchy aqueduct necessary ... 71
- Impervious strata—
  - Livermore Valley gravels ... 86
  - Sunol Valley gravels ... 197, 198
- Impossibility of conserving all the Alameda flood flow ... 85, 86
- Impounding of floods, reservoirs for ... 25-27
- Impounding reservoirs—
  - Boston ... 36
  - New York ... 43, 45
  - People's Water Company ... 177
- Improvement—
  - In municipal affairs ... 166
  - In quality of water by storage ... 32
  - In transportation facilities ... 166
  - Of existing roads ... 13
  - Of water by storage ... 36, 37
- Improvement clubs—
  - San Francisco, complaints of inadequate water supply ... 211, 213-218
  - San Mateo County, inadequacy of water supply ... 163
- Impurities eliminated by storage ... 53
- Inaccessibility adds to cost of high dams ... 28
- Inaccuracy of gaugings, Alameda Creek ... 82, 181
- Inadequacy of storage at Sunol ... 197, 198
- Inadequacy of supply—
  - Mokelumne River, South Fork ... 366
  - Of Spring Valley Water Works ... 64
  - Stanislaus River ... 303
- Inadequacy of water supply—
  - Daly City ... 164
  - Oakland ... 162, 163
  - Palo Alto ... 164
  - San Jose ... 163
- Inadequacy of water supply, San Francisco—
  - Complaints from the various districts ... 211-220
  - Location of complaints ... 212
  - Retarding building up of San Francisco ... 220
- Inadequate fire protection, San Francisco—
  - Complaints from the various districts ... 211-220
  - Fire Department, report on ... 211, 218, 219
- Inadequate storage facilities, McCloud River project ... 331
- Inadequate water mains, San Francisco ... 211

INDEX

Page

- Inadequate water pressure, San Francisco—
  - Complaints from the various districts 213, 214, 216, 217
  - Fire Department, report on 218, 219
- Inalienable right to unappropriated water of Tuolumne River to be reserved to bay cities 22
- Incapacity of Livermore Valley gravels to drink in flood flows 86
- Incidental construction costs—
  - Dove Creek pipe line 230
  - Elizabeth tunnel 223
  - Feather River project 352
  - Filtered water supply 325
  - Hetch Hetchy camp 287
  - Hetch Hetchy aqueduct 240
  - Hetch Hetchy aqueduct tunnels 246-249
  - Los Angeles aqueduct siphons 230
  - Los Angeles aqueduct tunnels 224-227
  - Method of arriving at 226, 227
  - Moccasin Peak tunnel 248
  - Mokelumne River project 369
  - Poopenaut dam 291
  - San Antonio pipe line 230
  - San Joaquin pipe 233
  - Stanislaus River project 308
- Incinerators 34
- Incipient sandstone, Los Angeles aqueduct tunnels 225
- Incline tunnel, Canyon Division 284
- Incline water chute, Tesla tunnel 283
- Income—
  - Peoples Water Company (1911) 177
  - Spring Valley Water Company (1911) 385
- Incompleteness of absorption, Alameda Creek gravels 196
- Increase in capacity—
  - Chabot Lake 134
  - Hetch Hetchy aqueduct tunnels 221, 222
- Increase in carrying capacity—
  - Hetch Hetchy aqueduct tunnels 221, 222
  - Pipe 122
- Increase in consumption of water—
  - East bay region 176
  - Marx, C. D., on 78
- Increasing demands of communities, east bay region 97
- Increase in discharge—
  - Hetch Hetchy aqueduct tunnels 221, 222
  - Pressure tunnels, in emergencies 221
- Increase in draft—
  - On Alvarado bay shore 70
  - On Niles Cone 70
- Increase in local use of water—
  - Alameda Creek 204
  - Livermore Valley 179, 187, 192
  - Mokelumne River 160a
  - Niles Cone 192, 204
  - Pleasanton Valley 179, 187, 192
- Increase in manufacturing plants, San Francisco 124
- Increase in percolating waters—
  - Coyote Valley gravels 207
  - Santa Clara Valley gravels 207
- Increase in population—
  - Dockweiler, J. H., on 76
  - Freeman, John R., on 76
  - Greater Oakland 76
  - Greater San Francisco 76
  - Hopson on 76
  - Manson, Marsden, on 76
  - Marx, C. D., on 76, 78
  - Oakland 76
  - Rural communities 77, 78
  - San Francisco bay communities 312
  - San Francisco, curves on 76
  - San Francisco, probable rate of 76, 77
  - San Francisco, school census 77
  - Santa Clara Valley 209
  - Schussler, Hermann, on 76, 78
  - Suburban communities 78
  - Urban communities 78

Page

- Increase in storage capacity
  - Chabot Lake 134
  - Crystal Springs reservoir 252
  - Merced Lake 126
- Increase in supply from Niles Cones 70
- Increase in use of water, per capita 79
- Independent source, Stanislaus River, inadequacy of 303
- Indian Bar, location of 116
- Indian Creek 259, 260
- Individual land holdings, subdivision of 77
- Industrial needs for water
  - American River 312
  - Cosumnes River 312
- Industrial use of ground waters 176
- Industries, Sacramento Valley 313
- Industry, establishment of branches of 176
- Infection carried by water, protection against 54
- Inferiority, Yolo basin water 317
- Infiltration—
  - Of brackish water 80
  - Of salt water 80, 176
  - Of water, Hetch Hetchy aqueduct 71, 121
  - Pressures, strength of circular cross-section against 221
  - To Alvarado wells 96
- Inflow—
  - Cherry Valley reservoir 33, 285
  - Eleanor Creek reservoir 33, 285
  - Hetch Hetchy reservoir 33, 285
  - Into gravels 201
- Ingleside District—
  - Inadequacy of water supply 220
  - No mains for fire protection 220
- Initial development—
  - American-Cosumnes project 313
  - Filtered water supply 325
  - Hetch Hetchy dam 286
  - Hetch Hetchy project 300
  - Mokelumne River project 366-369, 371-372
  - Poopenaut dam 293
- Injunction—
  - Against diversion of waters of Coyote River 206
  - Restraining diversion of percolating water 205
  - To restrain diversion of percolating waters a right belonging to owners of artesian wells 205
- Injurious effect of fluctuating water table 358
- Injury—
  - To Alameda County, by heavy draft on Niles Cone 80
  - To lands in irrigation districts through excessive use of water 83
  - To water supply, Palo Alto, through pumping by Spring Valley 96
- Insolubility of rock 53
- Installation of meters—
  - Effect on consumption of water 79
  - Peoples Water Company 177
  - Spring Valley Water Company 384
- Insufficiency—
  - Of borings, Alameda Creek watershed 188
  - Of surveys, Alameda Creek watershed 188
- Intake—
  - Alameda Creek gravels 197
  - Arroyo Valle 86
  - Arroyo Mocho 86
  - Crystal Springs 294
  - Early, Hetch Hetchy aqueduct 4
  - Eleanor-Cherry tunnel shafts 25
  - Filtered water supply 318
  - Gravel deposits, absorptive power of 196
  - Groveland tunnel 282, 284
  - Manson plan 143
  - McCloud River project 326, 332
  - Rio Vista 319
  - Sacramento River project 315, 317, 318
  - Sacramento Valley Irrigation Company 340
  - San Joaquin River project 315, 317, 318

Page

- Intake—
  - Santa Clara Valley, old channels 207
  - Santa Clara Valley gravels, underlying strata 208
  - Subterranean storage 196
  - Tesla tunnel 283
- Intensity of earthquake shocks 109, 110
- Intensive farming—
  - Bay region 124
  - Central California Valley 77
  - Future development of 187
  - Livermore Valley 85
  - Near city, advantage of 80
  - Niles Cone 91, 93, 94
  - Pleasanton Valley 85
  - Surplus water available for 21
  - San Francisco Bay lands 77
- Interception—
  - Percolating waters 205, 209
  - Rainwater 140
  - Stream flow 205
- Interchange of products with Orient 77
- Interchangeability, pressure tunnels 126
- Interest during construction, Hetch Hetchy aqueduct divisions .. 300, 301
- Interest payments on Tuolumne works cost saved for some years by building of Calaveras, San Antonio and Arroyo Valle reservoirs 68, 69
- Interference with output of wells 176
- Interference with rights—
  - Modesto and Turlock Irrigation Districts 357
  - Mokelumne River 366, 371
  - To percolating waters 205
- Interior Department—
  - Grants from of public lands for roads 29
  - Permit from desired by San Francisco to bore on national park lands 71
  - Permit from desired by San Francisco to take building materials for Hetch Hetchy construction from public lands 15, 22, 25
  - Permits from to build roads and electric lines 29
  - Sanction from to various works on Tuolumne River proposed to be erected by San Francisco 75
- Interior of steel pipe, protection of 229
- Interruption to service—
  - By earthquakes 110, 111
  - McCloud River project 344
  - Safeguards against 38, 129
  - San Miguel reservoir a safeguard against interruptions of service, Hetch Hetchy project 129
- Interstices in gravels 201
- Intrusion of serpentine, Hetch Hetchy aqueduct line 264
- Investigations—
  - By Freeman 75
  - Confirm early need of large new supply 82
  - Cost of saved in progress of work 75
  - Expensiveness of 75
  - Further 70
  - Immediate and thorough, favored by public opinion 70
  - Inadequacy of water supply, San Francisco 211-220
  - Necessary to determine cost of Hetch Hetchy project ... 71
  - Needs of Modesto and Turlock districts 82, 83
  - Of water companies' sources 70
  - Sections of San Francisco with inadequate mains 211
  - Should be limited to one source 75
  - Subdivision among experts 81, 82
  - Time for starting further 75
- Investment—
  - By San Francisco 72
  - Of new capital would be encouraged by mountain supply 69
- Iron pipe, east bay region 177
- Irregularity—
  - Alameda Creek run-off 196
  - Rainfall 195
  - Water bearing beds, Livermore Valley 200

Page

- Irrigable lands—
  - American River 311, 313, 314
  - Cosumnes River 311, 313, 314
  - Feather River 348
  - Niles Cone 204
  - Sacramento Valley 313
- Irrigated acreage—
  - Alameda County 78
  - Contra Costa County 78
  - Modesto District 359
  - Santa Clara County 78
  - Turlock District 359
- Irrigating—
  - Alfalfa, Decoto 92, 93
  - Alfalfa, Modesto and Turlock Districts 359
  - Apricot trees, Niles 93
  - Of Crops, Modesto and Turlock Districts 359, 360
  - Scenes, Niles Cone 92, 93
- Irrigation—
  - Bay region 124
  - Coyote Valley, prevented through diversion of storm waters 207
  - From Schell Ditch 307
  - Livermore Valley 85
  - Necessity of, in California 209
  - Niles Cone 91, 92, 93, 94
  - Niles Cone, annual quantity of water required for 204
  - Percolating water for 205
  - Pleasanton Valley 85
  - San Joaquin Valley from Stanislaus River 305
  - Superiority of underground waters for 209
  - Surplus water available for 21
- Irrigation canal—
  - Modesto Irrigation District 359
  - Oakdale Irrigation District 303
  - South San Joaquin Irrigation District 303
  - Turlock Irrigation District 359
- Irrigation demands—
  - Alameda County 78
  - Contra Costa County 78
  - On ground waters 80
  - San Francisco County 78
  - San Mateo County 78
  - Santa Clara County 78
- Irrigation, depth of—
  - Alameda County 78
  - Contra Costa County 78
  - Modesto Irrigation District 359
  - Santa Clara County 78
  - Turlock Irrigation District 359
- Irrigation districts—
  - Alkali area 358
  - Area of 358
  - Boundaries of 83
  - Construction cost of works 360
  - Crops raised 359, 360
  - Depth to water 358
  - Duty of water 357, 360
  - Excessive use of water for 357, 358
  - Needs for storage 360
  - Not injured through proposed diversion by City 83
  - Prior rights of 83, 358
  - Quantity of water put to beneficial use 82, 104, 359
  - Rainfall 358
  - Seepage waters 358
  - Soil condition 358
  - Should look to Stanislaus and Merced Rivers partly ... 83
  - Storage capacity of reservoirs 360
  - Temperature 358
  - Wells 358
- Irrigation of nearly a square mile by a million gallons daily .. 63
- Irrigation priorities—
  - American River 312
  - Cosumnes River 312
  - Stanislaus River 303, 304

INDEX

Page
Irrigation priorities—
  Tuolumne River . . . 61, 83, 101, 293
Irrigation pumping—
  Livermore Valley . . . 187
  Niles Cone . . . 91, 94
Irrigation requirements—
  American River . . . 311
  American-Cosumnes project . . . 313
  Cosumnes River . . . 311
  Feather River . . . 348
  Modesto Irrigation District . . . 82, 83
  Mokelumne River . . . 365
  Niles Cone . . . 94
  Sacramento Valley . . . 329
  Stanislaus River . . . 305, 307
  Tuolumne River . . . 82-83
  Turlock Irrigation District . . . 82, 83
Irrigation reservoir, Niles Cone . . . 94
Irrigation tracts, San Joaquin Valley . . . 305
Irrigation tunnels, Oakdale District . . . 221, 223
Irrigation use—
  Coyote River . . . 209
  Mineralizes water . . . 56
  Niles Cone . . . 91
  Of percolating water . . . 205
  Of surplus water carrying capacity, Hetch Hetchy aqueduct . . . 34
Irrigation water, measuring of . . . 33
Irrigators helped by release of stored waters by City . . . 83
Irvington-Calaveras Division—
  Description of . . . 241
  Length of . . . 241, 254
  Overhead charges . . . 300
  Unit costs . . . 254, 255, 258
Irvington-Chabot Division—
  Description of . . . 241, 290
  Length of . . . 241, 290
  Overhead charges . . . 301
Irvington gate house, Hetch Hetchy aqueduct—
  Branch aqueducts leading off from to bay cities . . . 20
  Connections with Crystal Springs reservoir . . . 252
  Cost of . . . 255
  Location . . . 20, 112
  Subdivision of water among the different communities . . . 21
  Terminal chamber and gate house for Hetch Hetchy aqueduct . . . 20, 123
Isabel Creek, prior rights of Bay Cities Water Company on . . . 96, 187
Islais and Salinas Water Company, rights and properties on Islais Creek . . . 385
Islais Creek as source of supply for San Francisco . . . 386
Islais Creek Valley junction and pipe line . . . 294, 295
Isohyetal lines—
  By Schussler . . . 197
  On rainfall . . . 100
  Stanislaus River drainage area . . . 302

Jacksonville, rock formation near . . . 276
Jasper rock, on peninsula line, Hetch Hetchy project . . . 124, 125
Jawbone Division, Los Angeles aqueduct . . . 224, 227
Jelly's Ferry, location of . . . 336
Joint canal—
  Modesto and Turlock Irrigation Districts . . . 305
  South San Joaquin and Oakdale Irrigation District . . . 307
Joint development of Tuolumne water supply by bay cities . . . 138
Jointing of rocks . . . 276
Joint use—
  Hetch Hetchy lands, for water supply and park purposes . . . 56
  Tuolumne water supply by bay cities . . . 161-165
Jones, Drenzy A., levels by . . . 108
Jones street tank, storage capacity . . . 390
Joost wells . . . 216
Junction points, alternative distribution aqueducts . . . 294

Katrine Loch—
  Coaching on roads in catchment area . . . 48

Page
Katrine Loch—
  Source of supply for Glasgow, Scotland . . . 48
  Steamboats crossing . . . 49
  Tourist travel . . . 48, 49
  Views . . . 48-50
Katz vs. Walkinshaw, decision relating to percolating waters . . . 205, 209
Kennedy Lake . . . 303
Kennedy Meadows . . . 303, 306
Kennison, Karl R., commendation for zeal in city's service . . . 160a
Kensico reservoir, views of . . . 45
Key map, wells in Livermore Valley . . . 89
Keystone, station on Sierra Railway . . . 289
Kidneys, gravel deposits . . . 198, 199
Kimball Island . . . 319
Klamath project tunnel . . . 250
Knight's Ferry—
  Dam owned by Tulloch near . . . 307
  Drop in river at . . . 307, 308
  Tunnel near . . . 276
  Water from Schell Ditch used near . . . 307
Knoxville formation—
  Branner, J. C., on . . . 111-113
  Chabot tunnel . . . 249, 291
  Composition of . . . 260
  Costs of tunnels through . . . 260, 265
  Occurrence on alternative distribution aqueducts, Hetch Hetchy project . . . 124, 125
  Occurrence, Hetch Hetchy aqueduct . . . 111, 112, 113
  Tesla tunnel . . . 264, 265
  Valle tunnel . . . 247, 260
Kolana rock—
  Location of . . . 11
  Views of proposed roadway near . . . 17, 19
Kuhn's Meadow . . . 303, 306
Kutter formula for computing carrying capacity of tunnels . . . 221, 222

Laborers' wages—
  California . . . 251
  Hetch Hetchy project . . . 240
  Los Angeles aqueduct tunnels . . . 223
  Southern Pacific bay shore tunnels . . . 251
  Use of on Hetch Hetchy pipe lines . . . 231
Lack of data—
  Alameda Creek yield . . . 88, 192, 193
  Run-off, Tuolumne River . . . 98, 99
Lack of fire protection, San Francisco—
  Complaints from the various districts . . . 211, 215, 216
  Report of Fire Department on . . . 218
  Streets on which there are no mains for fire protection . . . 219, 220
Lack of good reservoir sites, Mokelumne River . . . 160a
Lack of regularity, run-off, Alameda Creek . . . 196
Lack of water preventing expansion of San Francisco . . . 80
Lafayette tank, removed in 1902 . . . 389
La Grange—
  Discharge at . . . 99, 100, 101-103
  Gaugings at . . . 100
  Surplus water at . . . 101-103
  Waste waters . . . 101-103
La Grange dam—
  Built at joint expense of Modesto and Turlock districts . . . 357
  Construction of . . . 305
  Diversion of water at . . . 359
  Water wasted over . . . 360
La Grange Water and Power Company—
  Canal . . . 100
  Diversion by . . . 101, 102
  Prior rights of . . . 103, 106, 107, 285
Laidley street, San Francisco, view of . . . 217
Laguna Creek—
  Daily gaugings . . . 193
  Flow in . . . 86
  Location of . . . 112
  Sinking of wells on . . . 390
Lake Eleanor . . . 23
Lake Hemlock . . . 53

Page
Lake Kennedy 303
Lake Mahopac 45
Lake Merced Water Company owned rights at Lake Merced.. 385
Lake of the Woods, location of........ 310
Lake Skaneateles 53
Lake Thirlmere 46, 47
Lake Vernon 58
Lakeview District, San Francisco, no mains for fire protection. 220
Land near Early Intake, Hetch Hetchy, title to........ 22
Landowners—
  Niles Cone, rights of........ 179
  Rights to percolating waters........ 205
  Right to underground water paramount to that of an appropriator 208
  Santa Clara Valley, demands of........ 208
Land purchases—
  By San Francisco........ 138
  Cherry Valley 138
  Eleanor Valley 138
  Hetch Hetchy aqueduct, for the several divisions...... 300, 301
  Hetch Hetchy Valley 138
  Power house No. 2, Hetch Hetchy project........ 22
  Spring Valley Water Company........ 394
  Stanislaus River project........ 308
Landscape architectural treatment—
  Hetch Hetchy dam........ 288
  Marginal lands of reservoirs........ 38
  Poopenaut dam 291
Landscape beautified by dams and reservoirs........ 51
Lands—
  Cherry Creek watershed, owned by San Francisco.... 138
  Eleanor Creek watershed, owned by San Francisco.... 138
  Government, Poopenaut Valley........ 292
  Mokelumne River, owned by Sierra Blue Lakes Water and Power Company........ 369, 370
  Mokelumne River project........ 369
  Owned by Spring Valley Water Company.......384, 385, 394
  Poopenaut Valley, patented........ 292
  Required for filtered water supply........ 325
  Required for gauging weirs........ 33
  Required for Hetch Hetchy aqueduct........ 22
  Sacramento River project........ 325
  Spring Valley Water Company's ownership.......384, 385, 394
  Stanislaus River watershed, private ownership........ 303
  To which title is desired by San Francisco........ 13, 15
Large reservoirs a necessity on Sierra rivers........ 160k
Larger capacity of tunnel, cost relatively little more........ 140
Lava formation—
  Hetch Hetchy aqueduct........111, 115, 116
  McCloud River 329
Law—
  On use of artesian waters........ 205
  On water rights 342
  On use of percolating waters........ 205-210
Lawns and gardens—
  Denver 79
  Los Angeles 79
  San Francisco 79
  Watering of 79
Laying of pipe—
  Bay head pipe........ 236, 237
  Dumbarton Straits submerged pipe........ 123
  Islais Creek Valley........ 295
  San Joaquin Valley........229-235, 269
Leases of water for secondary purposes........ 21
Legal complications, Niles Cone........70, 74, 75, 81, 91
Legal difficulties, appropriation of ground waters........ 175
Legal expenses—
  Hetch Hetchy project........299, 300, 301
  Los Angeles aqueduct........ 299
  New York water supply........ 299
Legal rights—
  Land owners, Niles Cone........ 97, 187
  Owners of artesian wells........ 205
  Owners to percolating waters........ 205

Page
Legislation—
  Metropolitan water districts........ 164-166
  Necessary for consolidation of bay cities........ 166
Lessening of flow, Vernon Lake........ 16
Lenticular form, water bearing beds, Livermore Valley....... 200, 201
Letter—
  Doak, D. P., to Board of Public Works........ 327-330
  Freeman, John R., to City Attorney, in re McCloud River project 342-344
  Grunsky, C. E., to City Attorney, in re McCloud River project 338-341
  Lindley, Curtis H., to City Attorney, in re McCloud River project 341, 342
Levees, San Joaquin River........ 266-268
Levels—
  Correction of 108
  Hetch Hetchy aqueduct line........271, 272, 277
  Hetch Hetchy project........ 239
  San Antonio reservoir........ 256
  San Joaquin River crossing........ 266-268
  San Joaquin Valley 108
Levels, water—
  Hetch Hetchy 11
  Tuolumne River 108, 109
Liability insurance, Hetch Hetchy project........ 298
Liberality of Williams' estimate, Alameda Creek yield....... 187
Liberation of water—
  By power companies........ 356
  From Hetch Hetchy........ 304
  From Poopenaut reservoir........ 304
  Stanislaus River reservoirs........ 304
Licking Fork reservoir, diversion of water from Middle Fork Mokelumne River into........ 367
Lick Observatory, rainfall records at........ 193, 197
Life, steel pipe lengthened through use of cement lining...... 229
Limit—
  In supply of underground waters, Alameda Creek...... 86
  Of development, Mokelumne River........ 371
  To available storage, Livermore Valley gravels....... 200
Limitations of sub-strata........ 192
Limited capacity of Livermore Valley gravels........ 86, 87
Lincoln Mine—
  Length of tunnel........ 250
  Unit costs of tunnel........ 250
Lindley, Curtis H., letter to City Attorney in re McCloud River project 341, 342
Lining costs—
  Los Angeles aqueduct tunnels........ 224, 225
  Method of arriving at........ 226
  Western Pacific Railroad tunnels........ 251
  Yakima project tunnel........ 250
Lining—
  Hetch Hetchy aqueduct tunnels........ 120-122
  Los Angeles aqueduct tunnels........ 224, 225
  San Joaquin pipe........ 234, 235
  San Joaquin Valley shafts........ 265
  Steel pipe 21
  Strength against external seepage pressure........ 221
  Truckee-Carson project tunnels........ 250
  Tunnels 21
Lippincott, J. B.—
  Absorption of Livermore gravels........ 86, 88
  Errors in Spring Valley estimates on Alameda Creek yield 186-190
  Flow, Alameda Creek........ 85
  Gaugings Niles Canyon........ 83, 84
  On errors in Spring Valley records........ 180
  Rainfall table 199
  Report on Alameda Creek yield........ 186
Litigation—
  Between Spring Valley and San Francisco........63, 393, 394
  Ground waters, Alameda Creek........ 91
Littering of ground........ 34, 54
Little Cow Creek, power station at........ 327

Page

- Littlejohn Valley—
  - Mining operations 307
  - Water from Schell Ditch used in 307
- Little Lake Division, Los Angeles aqueduct 224, 227
- Livermore—
  - Possibilities of manufacturing use of water near 187
  - Possibilities of municipal growth near 187
  - Rainfall 87, 193, 194, 195, 197
  - Water used by 85
- Livermore area, soil survey 85
- Livermore Pass—
  - Elevation 323
  - Route of filtered water supply 323
- Livermore Valley—
  - Area of 85
  - Artesian water 88
  - Basin of 200, 201
  - Borings 192
  - Branner, J. C., report on 84, 191
  - Clay deposits 200
  - Composition of 201
  - Development of underground storage 86, 88
  - Evaporation from water surfaces in 199
  - Fertility of 187
  - Geological 86, 200
  - Impervious gravels 86, 88
  - Intensive farming 85
  - Irrigation 85, 187
  - Local use of water 179, 187, 190, 192
  - Local use of water the highest use 192
  - Movement of underground water 201
  - Natural filter 200
  - Outlet 201
  - Rainfall 193, 199, 201
  - Refill 200
  - Sands 199
  - Stratification 89, 90
  - Temperature 199
  - Torrential floods 188, 190, 197
  - Voids in sands and gravels 199
  - Water bearing strata 200, 201
  - Water duty 85
  - Width of distribution of clays 200
  - Wells 89
  - Yield of 199
- Livermore Valley gravels—
  - Absorption by 198, 201
  - Avoidance of tunneling through 259
  - Branner, J. C., report on formation 84, 191
  - Breadth 201
  - Capacity 197
  - Continuous flow 200
  - Depth 201
  - Dip in 259
  - Elevation of 197
  - Filling of pore spaces 201
  - Level of gravel bed 201
  - Limited capacity of 86, 87, 189, 200
  - Non-absorption of 87
  - Pliocene gravels 259
  - Pockety distribution of 200
  - Pore spaces 84, 201, 259
  - Rapid response to rain 86, 87
  - Regulating influence of 191, 196
  - Saturation of 259, 265
  - Storage capacity of 190
  - Tipping up of 190
  - Uneven distribution of 200
  - Water bearing character of 200
  - Williams, Cyril, Jr., report on 81
- Livermore Valley ground waters, report by Cyril Williams, Jr. 81
- Livestock—
  - McCloud watershed 336
  - Shasta National Forest Reserve 336
- Loading applied to Hetch Hetchy estimates 160p, 160q
- Loading costs—
  - Bay head pipe 236
- Loading costs—
  - Steel pipe, Los Angeles aqueduct 230, 231
- Lobos Creek
  - Abandonment of use of 387
  - Water supplied from by San Francisco City Water Works 385
- Local labor conditions—
  - Hetch Hetchy pipe lines 233
  - San Francisco 233
- Local overhead charges—
  - Hetch Hetchy dam 288
  - Hetch Hetchy project 300, 301
  - Local rainfall, vagaries of 194, 195
  - Local sources, further development of 71
- Local use of water—
  - Alameda Creek 85, 91, 187, 190, 204
  - Coyote Creek 208
  - Livermore Valley 179, 187, 190, 192
  - Livermore Valley, the highest use 192
  - Mokelumne River 160a
  - Niles Cone 192, 203, 204
  - Pleasanton Valley 179
  - San Pablo Cone 176
- Location, Hetch Hetchy aqueduct—
  - Studies for 262, 263
  - Profile of 271-274
  - Plan showing 271-275
- Location revised, Dry Creek tunnel 278
- Locations for canals and pipe lines, by Grunsky 108
- Locations, water, McCloud River 338, 339
- Loch Katrine 48, 50
- Locks Creek aqueduct 387, 388
- Log dams, Stanislaus River 304
- Logs, Alameda Creek wells 192
- Lombard street reservoir 131, 294, 387
- London, England 76
- Lone Tree Island 319
- Long, Percy V.—
  - Letter of transmittal to Advisory Board of U. S. Army Engineers 5
  - On doctrine of percolating waters 205-210
  - On formation of a municipal water district 161-165
  - On Greater San Francisco movement 165-166
  - On joint use by bay cities of Hetch Hetchy 161-164
- Long term averages, rainfall, error of relying on 197
- Lorigan, Judge, opinion in Miller vs. Bay Cities Water Co. 206-210
- Los Angeles—
  - Consumption per capita 79
  - Growth 78
  - Lawns and gardens in 79
  - Mountain source owned by 69, 138, 147
  - Necessity for obtaining additional supply 80
  - Problems of water supply 80, 138
  - Progressive development 153
  - Water supply, sanitary restrictions 33
- Los Angeles aqueduct—
  - Actual cost below estimated cost 223
  - Analyses of cost, steel pipe siphons 230-234
  - Built at lower cost than estimated 223
  - Carrying capacity of 128
  - Capacity far in excess of City's needs 145
  - Commission, report on 299
  - Comparison with Hetch Hetchy aqueduct 128, 226, 227
  - Cost of 330
  - Cost of data on tunnels 224, 225
  - Cost of haulage 242
  - Day labor used in construction 223
  - Diameter of 128
  - Electric power plants 227
  - Exceptionally able engineering 223, 226
  - Legal expenses 299
  - Overhead charges 227
  - Power development 128
  - Surplus capacity of 21

Page

- Los Angeles aqueduct—
  - Transmission lines ... 227
  - Tunnels on ... 128
  - Variety of formations ... 225, 226
  - Wages paid ... 252
- Los Angeles aqueduct tunnels—
  - Admirable quality of workmanship ... 223
  - Basis for incidental expenses ... 227
  - Bonuses paid ... 226
  - Character of rock ... 224, 225
  - Comparison with Hetch Hetchy tunnels ... 244, 245
  - Cost of ... 224, 225
  - Divisions of ... 224
  - Length ... 224, 225
  - Percentage timbered ... 224-226
  - Progress of work ... 224-226
  - Quantities ... 224, 225
  - Unit costs ... 224, 225
  - Wages paid ... 223
- Los Angeles pipe—
  - Equipment ... 233
  - General type of ... 230
  - Metal surface ... 233
  - Method of manufacture ... 230
- Los Angeles water supply problem, solution of ... 80, 138
- Loss—
  - Maintenance of Hetch Hetchy camp ... 287
  - Maintenance hospital, Hetch Hetchy ... 287
  - Of head ... 122
- Low—
  - Rainfall, series of years of ... 188, 197
  - Service area, San Francisco ... 212
  - Water, Hetch Hetchy reservoir ... 11
- Low cost, tunnel work—
  - Oakdale Irrigation District ... 223
  - San Joaquin Irrigation District ... 223
- Lowell street, San Francisco, view of ... 218
- Lower—
  - Strawberry reservoir ... 304
  - Uses of water ... 21, 22, 34
- Lowering of ground water, Niles Cone ... 94
- Lowering of water table—
  - Coyote Valley gravels ... 207, 209
  - Niles Cone ... 82, 91, 96, 175, 186, 204
  - San Leandro Cone ... 176
  - San Pablo Cone ... 176
  - Santa Clara Valley gravels ... 209
- Lowness of Manson estimates ... 143
- Lumber, unit prices ... 251
- Lumbering activities—
  - Feather River watershed ... 347
  - McCloud River watershed ... 335, 336
- Lumber camps—
  - Feather River watershed ... 347
  - Floating population ... 335
  - McCloud River watershed ... 335, 336
  - Stanislaus River watershed ... 303
- Lumber cutting—
  - McCloud River watershed ... 331, 343
  - Season of ... 335
  - Stanislaus River watershed ... 303
- Lumber mills, McCloud River ... 335
- Lunes, gravel deposits ... 198
- Lyons Flat reservoir ... 304
- Lyons Ranch ... 304
- Lyons Ranch dam ... 304, 305

- Mahopac Lake, view ... 45
- Mains, San Francisco—
  - Extensions to ... 64, 215
  - Inadequate in size ... 211, 215, 217, 220
  - Sizes of ... 131, 215-217, 220
- Maintenance—
  - Hetch Hetchy camp ... 286, 287
  - Hetch Hetchy dam ... 288
  - McCloud River project ... 330

Page

- Maintenance—
  - Poopenaut camp ... 291
  - Poopenaut dam ... 291
  - Roads ... 13, 15, 72
- Management, Hetch Hetchy water supply ... 299
- Manchester water supply, England ... 46, 47
- Manson, Marsden—
  - Estimates too low ... 143
  - Expression of appreciation of services for City ... 160s
  - Memorandum on McCloud River project ... 327
  - Mokelumne River investigation ... 160
  - On increase of population ... 76
- Manson plan of development—
  - Changes from Grunsky plan ... 142, 143
  - Comparison with Grunsky and Freeman plans ... 139, 140
  - Criticisms of ... 142, 144
  - Plan of 1911 conformable to Garfield permit ... 143
  - Variant on Grunsky plan ... 142, 143
- Manufacturing cost, cement ... 241
- Manufacturing—
  - Demands on ground waters ... 80
  - Increase in San Francisco ... 77
  - Plants, North Beach District ... 211
  - Use of water, Livermore ... 187
  - Use of water, Pleasanton ... 187
- Manzanita Water Company owns lands and rights at Portola ... 385
- Map—
  - American-Cosumnes project, rainfall ... 312
  - Bay Cities Water Company's supply, American-Cosumnes Rivers ... 310
  - Cherry Valley reservoir ... 26
  - East bay region water supply ... 172
  - Eleanor reservoir and dam site ... 27
  - Filtered water supply route ... 318
  - Hetch Hetchy aqueduct location ... 112-117, 277
  - Hetch Hetchy reservoir site ... 11
  - Livermore Valley wells ... 89
  - McCloud River project ... 326, 338, 342
  - Moccasin Creek crossing location ... 280
  - Niles Cone contours ... 95
  - Poopenaut reservoir site ... 292
  - San Antonio reservoir ... 256
  - San Joaquin River crossing ... 266-268
  - Stanislaus River watershed ... 302
  - Tuolumne River ... 4
- Marginal lands of reservoirs—
  - Boston water supply ... 36, 37, 38
  - Landscape, architectural treatment of ... 38
  - New York water supply ... 44, 45
- Mariposa formation ... 111, 116, 248, 276, 278, 279
- Market—
  - For California products, no limit to ... 77
  - Gardening, water for ... 80
- Market Street Homestead tract, San Francisco, no mains for fire protection ... 219
- Marsh lands—
  - Bay head pipe crossing ... 253
  - Cradles for steel pipe in ... 229, 230
  - Dumbarton Point ... 123
  - Niles Cone ... 203
  - Reclamation of ... 203, 204
  - San Joaquin River ... 122
- Martinez-Oakland tunnel, Feather River project, cost of ... 352, 353
- Marx, C. D.—
  - Discharge of Alameda Creek ... 82
  - Future demands, metropolitan water district ... 78
  - Increase in consumption ... 78
  - Increase in population ... 78
  - Quantity of water available from peninsula sources ... 81
  - Studies by ... 78
- Masonry—
  - Dams ... 119
  - Hetch Hetchy dam ... 287, 288
  - Poopenaut dam ... 291
- Massachusetts State Board of Health ... 36

INDEX

Page

- Mass curve—
  - Hetch Hetchy dam 285
  - Quantity of water available for City 101, 104, 106, 107
- Mass diagram, water available to San Francisco from Stanislaus River drainage area 306
- Mateo street, San Francisco, view of 217
- Materials for Hetch Hetchy construction, taking of from U. S. lands 15, 22, 25
- Maximum—
  - Cross-section, Hetch Hetchy dam 285
  - Cross-section, Poopenaut dam 293
  - Efficiency, steel pipe 229
  - Flow, McCloud River 334
  - Head, Alameda Creek crossing 258
  - Head, Mission Pass tunnel 258
  - Strain, Hetch Hetchy pipe 236
  - Strain, New York aqueduct 236
  - Stress, bay head pipe 237
- Mayor's letter of transmittal to Advisory Board 5
- McClintock vs. Hudson 205
- McCloud 335
- McCloud Gorge 336
- McCloud River—
  - Adverse rights to 342
  - Appropriations of water 329, 341
  - Dam site 333
  - Discharge 329, 330, 335, 339, 340
  - Diversion point 331, 332
  - Drop in 327, 331, 336
  - Fishing possibilities 336
  - Flow 329, 331, 334, 339, 340
  - Freedom from contamination 329
  - Freshets 334
  - Gaugings 329, 339, 340
  - Geological formations 329, 333, 334
  - Length of 334
  - Power possibilities 336
  - Prior rights on 341, 342
  - Railroads 335
  - Reliability of discharge 330
  - Remoteness of 331
  - Run-off 329
  - Source at Bartels 334
  - Source of 329
  - Springs 334
  - Summer population 331, 335
  - Survey by D. P. Doak 333
  - Tributaries 334
  - Velocity 335
  - Water 329, 330, 334
  - Water locations on 329
  - Water rights 338, 339
  - Watershed 329, 330, 336
- McCloud River Lumber Company 335
- McCloud River pipe line, route of 326
- McCloud River project—
  - Advantages of 330
  - Capacity 328
  - Comparison with Tuolumne River project 160i
  - Crossings 327, 328, 331, 332
  - Crudeness of proponents' maps 342, 343
  - Danger of interruption to service 344
  - Disadvantages of 157, 330
  - Diversion point 327
  - Filter plant near Martinez 332
  - Freeman, John R., on 160h, 160i, 342-344
  - Gray Rocks tunnel 332
  - Grunsky, C. E., on 331-333, 338-341
  - Grunsky, C. E., Jr., on 333-338
  - Inadequate storage facilities 331
  - Lindley, Curtis H., letter on 341, 342
  - Maintenance cost 330
  - Manson, Marsden, on 327
  - Map of 326
  - More expensive than Hetch Hetchy 344
- McCloud River project—
  - Necessity of detention of water in storage reservoirs as sanitary safeguard 343
  - Objections to 330
  - Operating cost 330
  - Power development 344
  - Power stations 327, 328
  - Pressure pipe 328
  - Proposition by D. P. Doak 327-330
  - Quantity of water available 328
  - Reliability of service 331
  - Route of aqueduct 327
  - Submerged pipe 328
  - Suisun Point reservoir 328
  - Suisun Point pumping station 328
  - Supply to bay cities 328
  - Supply to Sacramento Valley 328
  - Surveys 343
  - Topography 328
  - Transmission line 328
  - Type of construction 330
  - Under-estimation of cost by proponent 343
  - Use of natural channel for flow of water 327
- McMullin Lake, water level 266
- Meadow Lake—
  - Area of watershed 160a
  - Dam at 160a
  - Storage capacity 160a
- Meadows, Hetch Hetchy region 59, 60
- Mean—
  - Monthly discharge, City catchments relation to La Grange 99
  - Velocity of water, tunnels, Hetch Hetchy aqueduct 121
- Measurements—
  - Flow, Alameda Creek 181-185, 188
  - Flow, McCloud River 335, 339, 340
  - Of irrigation water 33
  - Of wells in irrigation districts 358
- Measuring weirs—
  - Alameda Creek 181
  - Hetch Hetchy dam 285
- Mechanical filters—
  - Cost of 324
  - Feather River project 352
  - Sacramento River 317
  - San Joaquin River 317
- Mechanical shop buildings, Hetch Hetchy 287
- Mechanics' wages, Los Angeles aqueduct tunnels 223
- Medley Lakes, location of 310
- Melting of snows—
  - Chief source of supply 32
  - Dates of 98
  - Mt. Shasta 329
  - Replenishment of storage by 11, 13
- Menace to purity of Feather River water through lumber camps 347, 348
- Merced drainage system 61
- Merced Lake—
  - Abandonment of use of 80
  - Daily draft on 383
  - Decrease in inflow into 126
  - Delivery of Hetch Hetchy water to 294
  - Elevation 131, 383
  - Increase in storage capacity 126
  - Increasing seepage from 126
  - Pollution of 81
  - Storage capacity 126, 131
  - Surface area of 388
  - To be regarded as a reserve 126
  - Water, weedy and unattractive 62
  - Yield of 126
- Merced Lake pumping plant 388
- Merced River should be drawn upon by irrigation districts 83
- Merging of bay cities 165, 166
- Merchants' Exchange, Oakland, special committee of 80
- Merrifield, A. D., et al 386

Page

- Metal surface—
  - Los Angeles pipe 233
  - San Joaquin pipe 233
- Meteorological—
  - Studies to be pursued by San Francisco 33
  - Tests at Prattville 100
- Metering, effect of 176
- Meters—
  - Drop in consumption through 79
  - For releasing priorities on Tuolumne River 83
  - Installation of 79
  - Peoples Water Company 177
  - Spring Valley Water Company 384
  - Union Water Company 178
- Metropolitan parks, reservoirs in 38
- Metropolitan Water Board, Boston 36, 38, 39
- Metropolitan Water District—
  - Action by Berkeley 162
  - Action by Oakland 162, 163
  - Action by San Jose 163
  - Bond issues by 164, 169, 170
  - Boston 9
  - Conducts wholesale business in water 64
  - Fixing of rates 170
  - Formation of 63, 64
  - Future demands of 78
  - Officers of 164, 169
  - Powers of 164, 168, 169
  - Promoting of 9
  - Provided for in Freeman plan of development 140
  - San Francisco Bay cities 9
  - Steps to formation of 164
  - Taxation 171
- Micro-organisms—
  - Cherry Valley reservoir 36
  - Eleanor Lake 36
  - Hetch Hetchy water 36, 138
  - Wachusett reservoir 36
- Middle Fork, Stanislaus River 303
- Middle Fork reservoir 306
- Middle service area, San Francisco 212
- Middlesex Fells reservoir 35-39
- Millbrae pumping station 294, 296, 297, 390
- Millbrae-San Mateo Division—
  - Description 297
  - Length 240, 297
  - Overhead charges 301
  - Tunnel aqueduct 297
  - Saving by use of pipe line instead of tunnel 297
  - Unit costs 297
- Millbrae-San Mateo tunnel aqueduct, capacity 297
- Miller, Clement H., maps McCloud River project 342, 343
- Miller Ranch 205-208
- Miller vs. Bay Cities Water Company 206-210
- Million gallons daily irrigates nearly a square mile 63
- Milpitas, prospects for future growth of 123
- Milwaukee, consumption per capita 79
- Mineral matter, freedom from, Sacramento River water 317
- Mineralization of water—
  - Sacramento River 56, 57, 317
  - San Joaquin River 56, 317
  - Through irrigation use 56
  - Tuolumne River 57, 317
- Mines, depth of 111
- Minimum flow—
  - Feather River 347, 348, 349
  - McCloud River 329, 339, 340
- Mining ditches, Mokelumne River 365
- Mining operations—
  - Littlejohn Valley 307
  - Stanislaus River watershed 303, 305
- Minor structures, basis of estimates on 251
- Miscellaneous expenses omitted from estimates, Hetch Hetchy aqueduct 240

Page

- Mission Pass tunnel—
  - Cost 255
  - Diameter 246, 255
  - Formations 246, 255
  - Internal pressures 255
  - Length 255
  - Location 255
  - Unit costs 246, 255
- Moccasin Creek—
  - Drop at 260
  - Elevations 108
  - Equalizing reservoir at 31
  - Formations 111, 279
  - Line of flow 116
  - Power station 29, 30, 139, 140, 141
  - Siphons 139, 141
  - Water level at mouth 108
- Moccasin Creek power house—
  - Construction deferred 280
  - Cost not included in estimate 280
  - Releasing water for priorities below 61
- Moccasin Creek region, accessibility of 281
- Moccasin-Early Intake Division—
  - Cost 300
  - Description 241
  - Length 241
- Moccasin Peak tunnel—
  - Cost 281
  - Diameter 248, 279
  - Formations 248, 279
  - Unit costs 248, 281
- Modern—
  - Machinery for San Joaquin pipe line 233, 234
  - Methods of electric haulage 226
- Model of gaugings, Alameda Creek 82
- Modesto canal, amount diverted 359
- Modesto Irrigation District—
  - Area irrigated 359
  - Construction cost of system 360
  - Diversion by 100
  - Excessive use of water in 83
  - La Grange dam 305
  - Needs of 21, 82, 83, 357
  - Percentage of land irrigated 359
  - Prior rights of 21, 83, 103, 106, 107, 285
  - Quantity of water put to beneficial use 104
  - Report by J. H. Dockweiler 82, 83, 357, 363
  - Stanislaus River originally adopted as water supply of 305
  - Water duty 85
- Modesto reservoir, storage capacity 358
- Modified project, Mokelumne River 371, 372
- Moffatt Bridge 108
- Moisture, transpiration and evaporation of 100
- Mokelumne gravity project, diagramatic profile of 160c
- Mokelumne Hill, rainfall 302
- Mokelumne River—
  - Area irrigable from 365, 366
  - Cost of structures 368
  - Dams 366
  - Discharge 365
  - Ditches 370
  - Established rights 366
  - Explored by power companies 366
  - Gravity supply from 160d
  - Hydrographic conditions 371
  - Irrigation requirements 365
  - Lack of good reservoir sites 160a
  - Less opposition to limited diversion than from Stanislaus or Tuolumne 371
  - Local use of water 160a
  - Middle Fork 367
  - North Fork 366, 367, 370
  - Prior rights on 366
  - Proximity 158, 160
  - Rainfall 366

INDEX

Page

- Mokelumne River—
  - Region 365, 371
  - Reservoir sites 160a, 366
  - Run-off 365
  - Source 365
  - South Fork 366, 367, 370
  - Storage possibilities 366
  - Storage reservoir 366
  - Water 370, 371
  - Watershed 160a, 365, 366
- Mokelumne River project—
  - As auxiliary to Tuolumne River project 366
  - As supplemental supply to another source 371
  - Comparison with Tuolumne River project 160c, 371
  - Conduit capacity 367, 369
  - Cost estimates 367, 372
  - Grunsky's conclusions on 371
  - Large local use of water 160a
  - Limit of development 371
  - Not available for ultimate requirements of bay cities 371
  - Paper location 367
  - Several times investigated by City and rejected 160
  - Use by San Francisco interfere with ultimate local development 371
- Monographs by H. Schussler 192
- Monopoly, water supply, San Francisco 384
- Montana, subterranean storage 198
- Monterey formation 111-113, 124-125, 249, 291
- Mortar, cost of 234
- Mosquitoes, Hetch Hetchy region 56, 148, 152
- Moss-like growth—
  - Boston aqueduct 221
  - Retarding effect of 221
- Mother Lode 110
- Mountains, Coast Range, location of 113
- Mountain Lake Water Company 385, 386
- Mountain run-off to valley rainfall, ratios of 105
- Mountain water supply—
  - Covered reservoirs for 129
  - Hetch Hetchy the best 75
  - Necessity for bay cities 71
  - Necessity for Oakland 162, 163
  - Preference for 69
  - Secured by other Pacific Coast cities 69, 138
  - Sources investigated 156
- Mt. Diablo route for filtered water supply 319-322
- Mt. Shasta, melting snows on 327, 329
- Mt. Shasta aqueduct 326-332
- Movable plant, Los Angeles aqueduct 227
- Movement—
  - Of underground water, Livermore Valley 201
  - Toward subdivision 77
- Mowry Slough, submerger crossing for Stanislaus project 308
- Muckers' wages, Los Angeles aqueduct tunnels 223
- Mucking, Elizabeth tunnel, unit cost 223
- Mud Creek 334
- Mulholland, Wm.—
  - Absorption of Livermore gravels 86, 88
  - Assumes no wastage at Sunol dam 187
  - Commendation for work on Los Angeles aqueduct 223
  - Cost of steel pipe 230
  - Criticism of estimate on Alameda Creek yield 180-201
  - Errors in estimates on Alameda Creek yield 186-190
  - Rainfall table 199
  - Report on Alameda Creek yield 186
- Multitubular gravel conduit 200
- Muniment title to D. P. Doak 341
- Municipal—
  - Affairs, improvement in 166
  - Purposes, use of water for 21
  - The highest use of water 21, 22
- Municipalities—
  - San Francisco Bay 9
  - Uniting of, in water district 9

Page

- Municipal water districts
  - Act for formation of 164, 167-171
  - Fixing of rates 170
  - Taxation 171
- Murphys, water supply of 305
- Mystic Lake reservoir 38, 42

- Napa cement works 242
- Narrowness, Hetch Hetchy gorge 287
- Nashua River 36, 145
- National Park Electric Power Company, patented lands owned in Poopenaut Valley 292
- Natural beauties—
  - Hetch Hetchy Valley 57
  - Of falls enhanced by storage 16
- Natural channels, use of 140, 142, 255
- Natural conditions—
  - Along Hetch Hetchy aqueduct 221
  - Elizabeth tunnel 223
  - Hetch Hetchy aqueduct tunnels 223
- Natural filter—
  - Automatic cleaning of 88
  - Clarifying of water 201
  - Clogging of 201
  - Detention of sand and silt 200
  - Livermore Valley 200
- Natural flow—
  - Pitt River 340
  - Sacramento River 340
  - Tuolumne River 285
- Natural lakes, chain of, American-Cosumnes project 310
- Natural regulator, Livermore Valley 189
- Navigable channel, Newark Slough 253
- Navigability—
  - Sacramento River 317, 336, 340
  - San Joaquin River 317
- Nearby gravel deposits for construction, Hetch Hetchy dam 287
- Nearly a square mile irrigated by a million gallons daily 63
- Necessity—
  - For detention reservoirs 158
  - Of additional water service, San Francisco 211
  - Of developing Hetch Hetchy reservoir to full capacity 286
  - Of early start on construction work 74, 75
  - Of filtration, Feather River water 348
  - Of filtration, Stanislaus River water 309
  - Of gravity flow water, without pumping, for San Francisco 124
  - Of high dam at Hetch Hetchy 119
  - Of investigation to determine cost of Hetch Hetchy project 71
  - Of irrigation, California 209
  - Of new roads for construction work 290
  - Of securing ample water rights for the future 138
  - Of storage, Alameda Creek 188
  - Of storage detention, Stanislaus water 309
- Needs, irrigation—
  - American River 312, 313
  - Cosumnes River 312, 313
  - Irrigation districts, from Stanislaus River 307
  - Modesto Irrigation District 21, 82, 83, 357
  - Turlock Irrigation District 21, 82, 83, 357
- Neglect of Hetch Hetchy 151, 152
- Negotiations for purchase of Spring Valley water properties 394, 395, 400
- Nevada City, rainfall at 302
- Newark Slough 253
- New roads, benefits of 149
- New York aqueduct—
  - Borings for 71
  - Lining costs 234
  - Maximum strain on pipe 236
  - Pressure tunnels 221
  - Siphons 122, 229, 232
  - Tunnels 121
- New York Board of Water Supply 44, 45, 119, 221, 299

Page

- New York City—
  - Consumption per capita ... 79
  - Increase in population ... 76
  - New water source sought by ... 187
  - Progressive development ... 153
- New York water problem, solution of ... 138
- New York water supply—
  - Administration expenses ... 299
  - Capacity of aqueduct ... 145
  - Condemnation proceedings ... 299
  - Esophus watershed ... 145
  - From Catskill Mountains ... 138, 145
  - Populated catchment areas ... 43-45
  - Reservoirs ... 43-45
  - Sanitary restrictions ... 32-33
  - Views of reservoirs ... 43-45
- Night evaporation ... 199
- Niles—
  - Irrigation at ... 93
  - Prospects for future growth ... 123
  - Strawberry farms ... 92, 93
  - Views near ... 92, 93
- Niles Canyon—
  - Diversion of flow from ... 189, 190
  - Flow past ... 83, 179
  - Gaugings at ... 83, 84
  - Out-flush of ... 94
  - Rainfall ... 84
  - Topography ... 84
  - Waste waters ... 85, 86, 179, 197
- Niles Cone—
  - Abstraction of water ... 94
  - Adverse rights ... 69, 74, 75, 179
  - Area of ... 172, 174, 203, 391
  - Available draft ... 173. 175
  - Communities on ... 204
  - Contest in courts on additional diversion ... 175
  - Danger point near ... 70
  - Depletion of ground waters ... 91
  - Depth to water in wells ... 204
  - Diversions by Peoples Water Company ... 203
  - Diversions by San Lorenzo Water Company ... 203
  - Diversions by Spring Valley Water Company ... 80
  - Draft on ... 70, 80, 81, 173. 175, 203
  - Duty of water ... 94, 204
  - Farming lands ... 203
  - Farmers ... 81, 91, 187
  - Fertility of ... 187
  - Ground contours ... 95
  - Height of ground water ... 91
  - Holding back water from ... 91
  - Intensive farming ... 91, 93, 94
  - Irrigating scenes ... 92, 93
  - Irrigation ... 91, 94
  - Legal questions ... 70, 74, 75, 81 91
  - Legal rights of land owners ... 187
  - Local use of water ... 175, 192, 203, 204
  - Location of ... 174
  - Lowering of water table ... 82, 91, 94, 96, 175, 204
  - Marsh lands ... 203
  - Nurseries ... 94
  - Outflow from ... 188
  - Outlines of ... 95
  - Outside use of water ... 175, 203
  - Overpumping of ground waters ... 70
  - Percolating waters ... 94, 175
  - Population ... 391
  - Problems on ... 74
  - Profile ... 95
  - Prolific supply from ... 175
  - Pumping of ground waters ... 70, 94
  - Quantity of water required for irrigation ... 94, 204
  - Quantity pumped from ... 203
  - Replenishment of ... 91, 94, 173, 175, 204
  - Report by J. H. Dockweiler ... 82, 203-204

Page

- Niles Cone—
  - Return water ... 204
  - Saltiness of water ... 70
  - Sands ... 89, 90, 91
  - Saturation ... 70, 80, 91
  - Seepage waters ... 94
  - Shortage of water ... 91, 94, 188
  - Source of supply ... 70, 91, 191, 192
  - Storage capacity ... 204
  - Test case in courts ... 70
  - Test wells should be sunk ... 70
  - Truck gardening ... 94
  - Views ... 92. 93, 203
  - Water contours ... 95
  - Water table ... 95, 204
  - Wells ... 177, 203, 204
- Niles dam—
  - Diagram ... 181
  - Flood flow ... 181
  - Views ... 182, 183
- Nine Mile Canyon, cost data on steel pipe siphons laid in ... 230-234
- No limit to markets for California products ... 77
- Normal flow, Coyote River ... 208, 209
- Northern sources of water supply—
  - Cost of pumping ... 157
  - Necessity for filtration ... 158
  - Objectionable harbor crossing ... 158
- North Beach District—
  - Manufacturing plants ... 211
  - Size of water mains ... 215
  - Views of ... 215
- North Fork—
  - Mokelumne River ... 160a, 367
  - Stanislaus River ... 303
- North Mountain—
  - Location ... 117
  - Power station at ... 143
- Norway, road in ... 14, 17, 18
- Not necessary to build high dams at Eleanor or Cherry at first ... 104
- Notices—
  - Against pollution of reservoir waters ... 36, 38, 39
  - Appropriation of water, McCloud River ... 338. 339
  - Sanitary regulations, Boston reservoirs ... 36
- No pumping, Freeman plan ... 142
- No right to water until actual diversion and use ... 342
- No water service, certain sections, San Francisco ... 213, 214
- Non-absorption of Livermore gravels ... 87
- Nurseries, Niles Cone ... 94

- Oakdale Irrigation District—
  - Area irrigated by ... 305
  - Canal ... 303
  - Diversion from Stanislaus River ... 303
  - Joint interest with South San Joaquin Irrigation District ... 307
  - Tunnels ... 221, 223
  - Wages for common labor ... 251
- Oakland—
  - Additional quantity available for ... 97
  - Consumption per capita ... 79
  - Annexation of Berkeley ... 166
  - Apparently hostile to Greater San Francisco movement. ... 166
  - Aqueduct to from Hetch Hetchy ... 20
  - Branch aqueduct to ... 123, 124
  - City Council ... 162, 163
  - Draft on Niles Cone ... 175
  - Inadequacy of water supply of ... 162, 163
  - Increase of population ... 76
  - Necessity for a mountain supply ... 162, 163
  - Population ... 163
  - Present sources supplying ... 162, 173-178
  - Public sentiment in favor of a mountain supply ... 162, 163
  - Resolutions on Hetch Hetchy by City Council ... 161
  - Rights to Hetch Hetchy source ... 162, 163

INDEX

Page

- Oakland—
  - Shrinkage of available supply for 94
- Oakland Division, meters installed 176
- Oakland Merchants' Exchange, special committee of 80
- Objections—
  - To bay crossing for pipe 127, 158, 321
  - To McCloud River project 330
  - To open storage 158
- Observations, rainfall, Sierra Nevada Mountains 302
- Obsolescence, Spring Valley Water Company 385
- Obstructing flow, Coyote River, injunction against 207
- Ocean slope creeks 96
- Ocean View District, San Francisco—
  - Complaints of inadequate water supply 211, 217, 218
  - Views of 217, 218
- Offer—
  - By City to purchase Spring Valley Water Works 395-400
  - By Sierra Blue Lakes Water and Power Company to sell properties to City 365-370
  - By Spring Valley Water Company to sell properties to San Francisco 394
  - Of Doak to sell McCloud River rights to San Francisco 328, 329
- Office furnishings, Hetch Hetchy camp 286
- Officials, conferences with 70
- Oifjord Lake, Norway, highway along 17, 18
- Oil fuel, cheapness of 31, 32
- Old ditches, Mokelumne River region 365
- Oleta ditch 370
- Oliver Salt Works 204
- Only sound engineering basis to begin by building Hetch Hetchy dam 144
- Opalescence, McCloud River water 334
- Open canals—
  - Elimination of under Freeman plan 142
  - Feature of Grunsky plan 139, 140
- Open channel connections, Hetch Hetchy project with Crystal Springs and San Andreas reservoirs 297
- Open reservoirs—
  - Disadvantages of 158
  - Within city limits 129
- Operation costs—
  - McCloud River project 330
  - Spring Valley Water Company 385
- Operations, Sierra and San Francisco Power Company, equalizing stream flow, Stanislaus River 305
- Opinions, Supreme Court on use of percolating waters 205-210
- Opportunities for San Francisco 77, 138
- Optimistic estimates—
  - Population 77
  - Spring Valley reserves for future growth 84
  - Underground water sources 200, 202
- Order—
  - Of presentation of City's case 7
  - Of Secretary of Interior 7
  - Of water supply development 62-75
  - To show cause by Secretary of Interior 312
- Ordinary proprieties sufficient for protection of water 36
- Organic life, water—
  - Destroyed by storage 37, 54
  - Eleanor Lake 36
  - Hetch Hetchy 36
  - Wachusett reservoir 36
- Orient, awakening of 77
- Origin, Livermore Valley refill 200
- Oroville 347
- Orphan asylum tunnel 251
- Out-crops, gravel, Alameda Creek 198
- Outflow—
  - Cherry Valley reservoir 33
  - Eleanor reservoir 33
  - Hetch Hetchy reservoir 33
  - Livermore gravel deposits 196
  - Niles Cone 188
  - Pleasanton gravel deposits 196
- Out-flush of Niles Canyon 94
- Outlet—
  - Alameda Creek gravels 197
  - Cherry Valley 25, 26
  - Eleanor Lake 23, 25, 27
  - Hetch Hetchy dam 10, 11, 13
  - Hetch Hetchy Valley 8, 11
  - Livermore Valley 201
  - Niles Cone 95
- Outlying districts, San Francisco—
  - Pipe mains supplying 212
  - Plan to secure adequate water supply for 211
- Output of wells 176, 177
- Outside sales of water, Spring Valley Water Company 385
- Outside use—
  - Of artesian waters 205
  - Of Coyote River waters 207, 208
  - Of Niles Cone water 175, 203
- Over-estimates—
  - By Mulholland on Alameda Creek yield 190
  - By Schussler on Alameda Creek yield 190
  - Of Alameda Creek yield 85, 97
  - Of undeveloped resources of water companies 69, 70
- Overflow from wells 206, 207
- Overflow dam, Early Intake 284
- Overflow lands, San Joaquin River 266-268, 270
- Overhead costs—
  - Hetch Hetchy aqueduct 298, 300, 301
  - Hetch Hetchy project 160p, 160q
  - Los Angeles aqueduct 239
- Overpumping—
  - Of ground waters, Brooklyn 70, 80
  - Of ground waters, Niles Cone 70, 80
  - Of wells 81
- Overlying land owners, adjustment of disputes between 205
- Owens River, intake on 128
- Owens Valley 199, 202
- Owners—
  - Of land, legal rights to percolating waters 205
  - Of superimposed lands, rights of, superior to those of appropriators 208, 209
- Ownership—
  - Hetch Hetchy Valley 13
  - Of lands by City and County in Tuolumne region 152
  - Reservoir sites, Stanislaus River 306
  - Riparian lands, gives no right to divert water out of watershed 341

- Pacific Coast cities, phenomenal growth of 78
- Pacific Gas and Electric Company 251, 365, 370
- Pacific Valley 160a
- Packing costs—
  - Hetch Hetchy aqueduct tunnels 246, 248, 249
  - Western Pacific Railroad tunnels 251
- Painting costs—
  - Dove Creek pipe line 230
  - Los Angeles aqueduct pipe 230, 232, 233
  - Portland aqueduct pipe 237
  - San Antonio pipe line 230
- Palo Alto—
  - City Council 163, 164
  - Daily consumption of water 164
  - Injurious effect on water supply of Spring Valley pumping 96
  - Population 164
  - Prospects for future growth of 123
  - Resolution by City Council on Hetch Hetchy 163, 164
  - Ultimate supply from Hetch Hetchy 164
- Panama Canal—
  - As affecting growth of San Francisco 144
  - Effecting reduction in freight rates 231
  - Opening of 77
  - Shipment of steel for Hetch Hetchy aqueduct via 231
- Paper location, Mokelumne River project 367
- Paradise for campers 59, 60

Page
Paramount right—
  Of land owner to underground water supply 208
  To replenishment of underground storage Niles Cone 97
Park Lane Tract, San Francisco, no mains for fire protection 219
Park purposes, use of Hetch Hetchy lands for 56
Parks, Hetch Hetchy region 59, 60
Park-Richmond Improvement Club, San Francisco, complaint of inadequate water supply 213
Park rules 54, 55
Parkside—
  Hydrants found dry 219
  View of 218
Partial emptiness of reservoirs 187
Pasadena, consumption per capita 79
Patented lands—
  Owned by National Park Electric Power Company 292
  Poopenaut Valley 61, 292
Pathogenic germs—
  Destruction through storage 348, 366
  Die in storage reservoirs 32
  Storage period necessary for destruction of 349
Patten, F. B., reservoir site, Stanislaus River, owned by 306
Patterson, Thos. J., reservoir sites, Stanislaus River, owned by 306
Peat, corrosive action upon steel 319
Peaty soil 319
Pebbles—
  In gravel, varying size of 202
  Resulting from attrition 202
Peninsula—
  Alternate aqueduct on 294-298
  Earthquake faults 323
  Ground waters 81
  Hetch Hetchy supply to 21, 124, 125, 294-298
  Pipe line 294
  Reservoirs 388, 391
  Sources of supply 87
  Surface supplies from 61
  System of Spring Valley Water Company 383
  Tunnel on 123
  Watersheds 391
  Western slope sources 81
Peoples Water Company—
  Additional supply by 80, 175, 176
  Boosters 177
  Capacity 177
  Circular on Hetch Hetchy water supply 160j
  Communities served by 63, 177
  Condemnation of 63
  Consolidation of water companies into 177
  Diversions from Niles Cone 203
  Division of sources of supply 172, 176, 177
  Draft on sources 174
  Expenditures by 177
  Filter plants 177
  Future yield 81
  Greater water supply 175, 176
  Meters 177
  Pipe lines 177
  Present yield 81, 82
  Pressure zones 177
  Pumping stations 177
  Purchase of 63
  Rates received by 177
  Reserves exaggerated 82
  Reservoirs 177
  Revenue 177
  Service areas 177
  Services 177
  Sources of supply 172, 177
  Statistics on 177
  Taxed to utmost to meet demands 173
  Watershed areas of 172
  Yielding capacity 81, 82
Per capita consumption—
  East Bay region 174
Per capita consumption—
  Eastern cities 79
  Oakland 79
  Pacific Coast cities 79
  San Francisco 79, 383
Per capita increase in use of water 79
Percentage—
  Increase in population, San Francisco 77, 78
  Metered services, Oakland division 176
  Precipitation to run-off, Eleanor watershed 101
  Precipitation to run-off, Hetch Hetchy watershed 101
  Rainfall to run-off, Alameda Creek 88
  Run-off to rainfall 194, 195
  Timbering of Hetch Hetchy tunnels 246-249
Percolating waters—
  Absolute right of landowner to abstract 209
  Appropriation of 205
  Common law rule on 205, 209
  Conveyance of for distant use 205
  Coyote River 206, 210
  Decisions on diversion of 97
  Depletion of 209
  Diversion of 97, 205
  Doctrine of 205, 210
  Injunction restraining diversion of 205
  Interception of 205, 209
  Interference with rights to 205
  Niles Cone 94, 175, 186
  Owners of artesian wells entitled to injunction to restrain diversion of 205
  Rights to 94, 186
  San Francisco Bay 80
  Santa Clara Valley 208
  Use for irrigation 205
Period of storage, Alameda Creek gravels 196, 197
Permits desired by city—
  For building roads 29
  For reservoirs on public lands above Hetch Hetchy 28
  To bore on national park lands 71
  To take building materials from public lands 15, 22, 25
Pescadero Creek—
  Dam site 96
  Gaugings 96
  Quantity available from 81
  Smallness of supply 96
Petition for constitutional amendment on Greater San Francisco 165
Pfieffer Springs and tunnels 177
Phenomenal growth of Pacific Coast cities 78
Philadelphia—
  Consumption per capita 79
  Increase in population 76
Phoenix reservoir 305
Picnickers—
  Boston reservoirs 35
  Exclusion of from catchment areas 35
Piedmont Springs 177
Pilarcitos dam 386-387
Pilarcitos pumping station 390
Pilarcitos reservoir—
  Capacity 65
  Construction of 386-387
  Elevation 131
  Storage capacity 131
Pilarcitos watershed, care at 61
Pinole Creek 176
Pinole reservoir 176
Pinole, supplied by Hercules Water Company 178
Pipe—
  Cost 279, 283, 291, 295
  Crossings 321-322
  East bay region 177
  Joints 232
  Laying 123, 236-237, 269
  Lining of 122, 237
  Pitting of 229

Page

- Pipe—
  - Preservation from rust 21
- Pipe lines—
  - American-Cosumnes project 310
  - Bay head 123, 253
  - Carrying capacity of 21, 122
  - Crystal Springs 64, 294
  - Filtered water supply 324
  - Freeman plan of development 139-140
  - Grunsky plan of development 139-141
  - Hetch Hetchy, route of 20, 112-115
  - Injured by earthquake 127
  - Locations by Grunsky 108
  - Los Angeles aqueduct 227
  - Manson, plan of development 139-140
  - On peninsula 64, 295-296
  - Peoples Water Company 177
  - Portland aqueduct 237
  - San Joaquin Valley 114-115, 122
  - Saving as against tunnels 297
  - Union Water Company 177-178
- Pitting of steel pipe 229
- Pitt River 196, 327, 340, 342
- Pitt River crossing 332, 337
- Pittsburgh aqueduct 229
- Placerita Canyon 230-234
- Placing costs—
  - Bay head pipe 236
  - Los Angeles aqueduct 230, 231-232
- Plan—
  - Early intake 282
  - Hetch Hetchy aqueduct location 112-117, 261, 277
  - Hetch Hetchy dam 118, 285
  - Hetch Hetchy pipe location 271-275
  - Moccasin Creek crossing location 280
  - Poopenaut dam 293
  - Poopenaut reservoir site 292
  - Power house No. 2, Hetch Hetchy project 282
  - San Antonio dam 257
  - San Antonio reservoir 256
  - San Joaquin River crossing 266-268
  - Tesla tunnel 280
- Plan of development—
  - By Freeman 139
  - By Grunsky 138-144
  - By Manson 138-144
  - Differences between those of 1902 and 1912 140
  - Under Garfield permit 138
- Plane, lowering of—
  - Coyote Valley gravels 207
  - Niles Cone 82, 91, 94, 96, 175, 204
- Plane of saturation—
  - Fluctuation of 198
  - Lowering of 82
  - Niles Cone 70, 80, 91
- Planes, vertical cleavage 276
- Planning of future water supply 189
- Plant, maintenance and repairs, Poopenaut dam 291
- Plant transpiration, evaporation through 189
- Plastering costs—
  - Los Angeles aqueduct tunnels 224-225
  - Method of arriving at 226
- Playfair 304
- Pleasanton—
  - Rainfall 193
  - Swamp lands north of 199
  - Water used by 85
  - Yield above 186
- Pleasanton ground waters 61, 69
- Pleasanton Valley—
  - Area of 85
  - Borings 191
  - Development of water resources 193
  - Intensive farming 85
  - Irrigation 85
  - Local use of water 179
  - Porous beds 86

Page

- Pleasanton Valley—
  - Topography of 86
  - Torrential floods 188, 190, 197
  - Turbidity of streams through 201
  - Underground storage in 86
  - Water duty 85
- Pleasanton Valley gravels—
  - Absorbing of floods 86
  - Depletion of storage 198
  - Depth of deposit 198
  - Elevation of 197
  - Pumping of 86
  - Regulating influence of 191, 196
  - Storage capacity of 190, 197
  - Tipping up of 190
- Pleasanton water 201
- Pleasanton wells 81, 97, 191, 390
- Pleasure boats on reservoirs 49
- Pleasure of public, roads for 15
- Pliocene gravels 88, 110-11, 112-114, 221, 247, 259, 260, 263
- Plows, use of 233-234
- Plugging up of gravel conduit 200
- Plumas County 348
- Plums—
  - In Hetch Hetchy dam 287
  - In Poopenaut dam 291
- Plymouth (Mass.), wrought iron street mains of 229
- Portola dam 385, 389
- Portola reservoir 383
- Point of diversion—
  - McCloud River 341
  - Stanislaus River 305, 307
- Police supervision against pollution 38
- Policing—
  - Camp, Hetch Hetchy 287
  - Watershed, McCloud River 331
- Political interests, effect on wages 252
- Polluted waters purified by storage 53
- Pollution—
  - Chance, prevented by storage 38
  - Defense against 54
  - Feather River water 347-348
  - Hetch Hetchy waters 13
  - Lake Merced 81
  - Precautions to prevent 55
  - Protection from 13, 34
  - Sacramento River water 317
  - San Joaquin River water 317
  - Stanislaus River water 303, 307
  - Tuolumne River water 284
- Poopenaut camp 291
- Poopenaut dam 160r, 241, 291, 293
- Poopenaut dam site 291-292
- Poopenaut Meadows 58, 60-61
- Poopenaut reservoir 160r, 241, 291-293
- Poopenaut reservoir site 291-292
- Poopenaut Valley 60-61, 160r, 241, 291-293
- Poor circulation, water service, San Francisco 216
- Pope Tract, San Francisco, no mains for fire protection 219
- Popular appreciation of Tuolumne source 72-73
- Populated catchment areas—
  - Boston 53
  - Feather River 347
  - McCloud River 335, 343
  - New York 43, 53
  - Stanislaus River 303
- Population—
  - Bartels 335
  - Bay region 312
  - Chart 78
  - Curves 76
  - Density of 77-78
  - Dockweiler, J. H., on 312
  - East bay region 173-174
  - Future, San Francisco Bay communities 77
  - Greater San Francisco 76-77
  - Increase in 78, 152

Page

- Population—
  - Marx, C. D., on, 78
  - McCloud, 335
  - Niles Cone region, 391
  - Oakland, 163
  - Palo Alto, 164
  - Plumas County, 348
  - San Francisco, 76-77, 152
  - San Francisco district, 312
  - San Jose, 163
- Populous communities, reservoirs in, 35, 38
- Pore space—
  - Gravels, packing with silt, 200
  - Livermore Valley gravels, 86, 88, 201
- Porosity—
  - Alameda Creek gravels, 196-197
  - Livermore Valley gravels, 259
  - Sunol Valley gravels, 197, 259
- Porous gravels—
  - Alameda Creek, 196-198
  - Arroyo Mocho, 201
  - Arroyo Valle, 201
  - Livermore Valley, 86, 191, 201
  - Pleasanton Valley, 86
  - Porphyrite, 111, 115-116, 225, 248-249, 276, 278, 283
- Portland (Ore.)—
  - Aqueduct, 138, 237
  - Consumption per capita, 79
  - Forest reserve established by, 147
  - Mountain source owned by, 69, 147
  - Pipe lines on water supply, 147, 237
- Portulaca, 4, 105
- Possibilities of surface storage, Alameda Creek, 88
- Posting of notice confers no right to the water, 342
- Posting of notices at reservoirs as sanitary precaution, 36
- Postponement of order to show cause by Secretary of the Interior, 312
- Potability—
  - American River water, 313
  - Cosumnes River water, 313
  - Sacramento River water, 317
  - San Joaquin River water, 317
- Potentialities for growth of San Francisco, 77
- Potrero Heights District, inadequate water supply and fire protection, 220
- Potrero Heights reservoir, 131, 390
- Potrero, manufacturing in, 124
- Potrero tunnel, 251, 296
- Power—
  - Asset, value of, 31-32
  - Business prohibited to City by charter, 31
  - Delivery, 31
  - For construction, 119
  - Stimulus of, 187
- Power companies—
  - Control of Yuba watershed, 355
  - Liberation of water by, 356
- Power development—
  - American-Cosumnes aqueduct, 311
  - Cost small, Hetch Hetchy, 31
  - Fall utilizable, Hetch Hetchy, 29, 30-31
  - Feather River, 100, 199
  - Freeman plan, 141
  - From water released for priorities, 61
  - Grunsky plan, 140-141
  - Hetch Hetchy aqueduct, 29-31, 61, 128
  - Horsepower produced, 30-31
  - Los Angeles aqueduct, 128
  - Manson plan, 143
  - McCloud River project, 327-328, 344
  - Moccasin Creek, 280
  - Stanislaus River project, 308
  - Subordinate to domestic water supply, 31
  - Rich Gulch, 367
  - Yuba River, 355-356
- Power house, Angel's Creek, 305

Page

- Power houses, Hetch Hetchy project—
  - At Cherry River mouth, 73, 160r
  - At Moccasin Creek, 280
  - Freeman plan, 139-141
  - Grunsky plan, 139, 140-141
  - Manson plan, 139
  - No. 1, 4, 29. 109, 116-117
  - No. 2, 4, 22, 30, 282, 284, 286
  - No. 3, 30
- Power plant, temporary, 73
- Power possibilities—
  - American-Cosumnes aqueduct, 311
  - Hetch Hetchy aqueduct, 29
  - McCloud River, 336
- Power stations, McCloud River project, 328, 337
- Power transmission lines, 15, 31
- Prattville, meteorological tests at, 100
- Precautions to prevent pollution, 55
- Precipitation—
  - Alameda Creek watershed, 193, 194-195
  - Eleanor watershed, 101
  - Hetch Hetchy watershed, 101
  - High Sierras, 99-100
  - Mountain catchments exceed those at outlets of valleys, 105
  - Proportion to run-off, 100
  - Railroad Flat watershed, 366
  - Relation to run-off, 98
- Precita Valley emergency pumps, 131
- Preference for a mountain water supply, 69
- Preliminary studies, scope of, 71
- Premium rate, employers' liability insurance, 298
- Preparation of foundations—
  - Hetch Hetchy dam, 287
  - Poopenaut dam, 291
- Present needs necessitate broadening of Garfield permit, 140
- Present sources—
  - Additional supply from, 97
  - East bay region, 173-178
  - Studies of, 82
  - Ultimate decrease in yield of, 81
  - Yield of, 80
- Present supply—
  - Increase in, 69-70
  - Quality of, 61
- Preservation of water to lands overlying water bearing strata for reasonable use, 209
- Presidio Heights tank, 131, 212, 389
- Pressure—
  - Bay head pipe, 236
  - Fire hydrants, San Francisco, 215, 218-219
  - Flood waters. Coyote Creek, 209
  - Hetch Hetchy aqueduct tunnels, 221
  - Inadequacy for water service, San Francisco, 206, 207, 213-214, 216-218
  - San Bruno tunnel, 295
  - Storm waters, Santa Clara gravels, 208
  - Tanks, control in developing power, 221
- Pressure tunnels—
  - Advantages of, 121
  - Alternative distribution aqueducts, 294
  - Discharge, 221
  - Hetch Hetchy aqueduct, 120, 252, 255, 258, 259-260, 264-265, 276, 278-281, 283-284, 289, 294-295
  - Interchangeability, 126
  - New York water supply, 221
  - Preference for by John R. Freeman, 138
- Pressure zones, Peoples Water Company, 177
- Prevention of defiling of water, 13, 34
- Priest's Hill, 242, 289
- Priest's Hotel, 109
- Primary right of land owner to full flow of underground water, 208
- Prince, George T.—
  - Estimate on Lake Chabot, 134
  - Report on irrigation requirements, 357
- Principles of law, use of percolating waters, 205-206

INDEX

Page

- Priority—
  - La Grange Water and Power Company 285
  - Modesto Irrigation District 285
  - Of appropriation, percolating waters 205
  - Turlock Irrigation District 285
- Priorities—
  - Alameda Creek 187
  - Allowance for 101-103
  - American River 312
  - Calaveras Creek 187
  - Cosumnes River 312
  - Could be released by meters 83
  - Mass curve diagram allowing 285
  - Modesto and Turlock Districts 21, 33, 83, 358
  - Mokelumne River 366
  - Release of water for 33, 101, 104
  - Satisfaction of 101-104, 106-107
  - Stanislaus River 303-304-305
  - Tuolumne River 8, 285
  - Yuba River 355
- Prior rights—
  - American River 312
  - Bay Cities Water Company 187
  - Cosumnes River 312
  - McCloud River 341-342
  - Modesto and Turlock Districts 21, 33, 83, 358
  - Mokelumne River 366
  - Pitt River 342
  - Sacramento River 342
  - Stanislaus River 303-304-305
  - To be supplied from Poopenaut reservoir 293
  - Tuolumne River 8, 285, 293
  - Yuba River 355
- Privately owned lands—
  - American River watershed 312-313
  - Cosumnes River watershed 312-313
  - Stanislaus River watershed 303
- Private wells 81, 174
- Probable increase in population 77
- Problems of water supply 80
- Profile—
  - City Pipe System 131
  - Flood levels, Alameda Creek 181, 184
  - Freeman plan of development 139
  - Grunsky plan of development 139
  - Hetch Hetchy aqueduct location 277
  - Manson plan of development 139
  - Niles Cone 95
  - Niles dam 181
  - Run-off Tuolumne River 101-103
  - San Joaquin River crossing 267
  - Stanislaus River project 309
  - Sunol dam 184
- Profiles—
  - Alternative distribution aqueducts 125
  - Hetch Hetchy aqueduct 271-274
  - San Miguel reservoir 132
- Profit, contractor's, Hetch Hetchy project 298-300
- Profit in commisary, Hetch Hetchy camp 287
- Progress of work—
  - Los Angeles aqueduct 226
  - Portland aqueduct 237
- Progressive development—
  - Boston 153
  - Los Angeles 153
  - New York 153
  - Seattle 153
- Progress of San Francisco retarded by inadequate water supply 220
- Prolific supply from Niles Cone 175
- Property rights—
  - Percolating waters 205
  - San Francisco 152
- Propagation of germs, stored water 37, 54
- Proportion of run-off to precipitation 100
- Proposal for purchase by San Francisco of the Spring Valley Water Works 395-400

Page

- Proposed general order of water supply development 62-75
- Proposition of D. P. Doak to San Francisco 328-329
- Protection
  - For City's rights 72
  - From pollution 13, 34, 38, 54, 138
  - Of courts for rights to percolating water 205
- Proximity—
  - Mokelumne River 158-160
  - Stanislaus River 158-160
  - Tuolumne River 158-160
- Prudency of building
  - Arroyo Valle reservoir 190, 192
  - Calaveras reservoir 190, 192
  - San Antonio reservoir 190, 192
- Public—
  - Freely admitted to Boston reservoirs 36
  - Opinion adverse through court decisions on ground waters 176
  - Sentiment in favor of mountain supply for Oakland 162
  - Spirit against defiling of water 47
  - Use of reservoir catchments 38-47, 51
  - Welfare, basis of City's action in securing water supply 312
- Public lands—
  - Borings on 71
  - Taking of construction materials from 15, 22, 25
- Public service corporations, east bay region 174, 176
- Public water supply—
  - Sacramento River water unsuitable for 317
  - San Joaquin River water unsuitable for 317
- Pumping—
  - American-Cosumnes project 311, 313
  - Court decisions on 80-81
  - Elimination of, Freeman plan 142
  - Feather River project 353
  - For irrigation, Livermore Valley 187
  - For irrigation, Niles Cone 70, 91
  - Pleasanton gravels 86
  - Stanislaus River project 308
  - Subterranean reservoir 86
- Pumping station—
  - Alternative distribution aqueducts 294
  - Hercules Water Company 178
  - Rio Vista 319
  - San Lorenzo Water Company 178
  - Stanislaus River project 308
  - West San Pablo Land and Water Company 178
- Pumping stations—
  - Filtered water supply 318
  - Peoples Water Company 177
  - Sacramento River project 320-321
  - San Joaquin River project 320-321
- Pumps, equalizing action of 38
- Purchase—
  - Of Cherry Creek lands and rights by City 138
  - Of lands required for the various divisions of the Hetch Hetchy aqueduct 300-301
  - Of public utilities by City 63
  - Of rights of way for the several divisions of the Hetch Hetchy aqueduct 300-301
  - Of Spring Valley Water Works 62-63, 138, 395-400
- Purification of water—
  - By exposure to sunlight 38, 42
  - By sedimentation 38, 42
  - By storage 32, 36, 37, 42, 43, 48, 53, 54, 57
  - Feather River project 349
  - Sacramento River project 317
  - San Joaquin River project 317
- Purifying power of soil 54
- Purity of water—
  - Alameda Creek 198
  - American River 314
  - Cosumnes River 314
  - Hetch Hetchy 138
  - McCloud River 329, 330
  - Tuolumne River 53, 57

Page

- Qualitative character of Livermore Valley gravels ... 200
- Quality—
  - Of roadbeds ... 13, 15
  - Of sub-strata rock ... 71
- Quality of water—
  - Alameda Creek ... 61, 194
  - American River ... 313
  - Cosumnes River ... 313
  - Eel River ... 346
  - Hetch Hetchy ... 138
  - Important factor in determining source ... 147, 151
  - Improved by storage ... 32
  - McCloud River ... 329
  - Mokulmne River ... 370
  - Pleasanton ground waters ... 61
  - Sacramento River ... 317
  - San Joaquin River ... 317
  - Spring Valley ... 61
  - Stanislaus River ... 309
  - Sunol ground waters ... 61
  - Tuolumne River ... 53-57
- Quantity of water available—
  - Daily under Freeman plan ... 139, 140
  - Daily under Grunsky plan ... 139, 140
  - From Bay Shore gravels ... 81
  - From ocean slope creeks ... 81
  - To San Francisco from American-Cosumnes source ... 311, 313
  - To San Francisco from Feather River ... 348
  - To San Francisco from McCloud River ... 328
  - To San Francisco from Stanislaus River ... 305, 306, 307
  - To San Francisco from Tuolumne River ... 101-107, 361-363, 285
  - To San Francisco if priorities are restricted to maximum that can be beneficially used ... 101-103
- Quantity of water pumped from Niles Cone ... 203
- Quantity of water required—
  - By irrigationists, American-Cosumnes project ... 313, 314
  - By San Francisco, Marx on ... 78
  - For future needs ... 81
  - For intensive farming ... 80
  - For market gardening ... 80
- Quantity of water that can be diverted from Tuolumne River by City without encroaching on prior rights ... 21
- Quantities—
  - Arroyo del Hambre reservoirs ... 349
  - Cherry Valley dam ... 289
  - Eleanor dam ... 289
  - Hetch Hetchy aqueduct tunnels ... 120
  - Hetch Hetchy dam ... 118, 285, 287, 288
  - Los Angeles aqueduct tunnels ... 224, 225
  - McCloud River project ... 326
  - Poopenaut dam ... 293
  - San Bruno tunnels ... 238
  - San Leandro dam enlargement ... 135
- Quicksand—
  - Livermore Valley ... 89, 90
  - Los Angeles aqueduct tunnels ... 225
- Quigley Canyon, cost data on steel pipe siphons lain in ... 230-234

- Railroad—
  - Cuts, unit costs ... 251
  - Lines of ... 112-115
  - McCloud River watershed ... 335
  - Near shaft sites ... 265
  - On catchment areas ... 43, 53
  - Rails on roads ... 13
  - Rate for cement ... 242
  - Rate paid for common labor ... 251, 252
  - Rosasco to Hetch Hetchy ... 290
  - Stations on Sierra Railway ... 289
  - Temporary, for construction ... 74, 286, 290
  - Tunnels, unit costs ... 250, 251
  - Within easy reach of working points, Hetch Hetchy aqueduct ... 289
- Railroad Flat dam ... 160a
- Railroad Flat reservoir ... 160a, 367, 368
- Railroad Flat watershed ... 366

Page

- Rainfall—
  - Alameda Creek watershed ... 175, 192, 194, 195, 196, 197, 199
  - American-Cosumnes watershed ... 312-314
  - American River ... 313, 314
  - Calaveras damsite ... 88, 193
  - Chart by Schussler ... 197
  - Cherry River watershed ... 105
  - Contours ... 197
  - Cosumnes River ... 313, 314
  - Coyote River watershed ... 206
  - Curves ... 199
  - Cycle of years of low ... 188
  - Distribution of ... 190, 193
  - Diversity in ... 193
  - Eleanor watershed ... 99, 105
  - Error of relying on long term averages ... 197
  - Evaporation ... 195
  - Hetch Hetchy watershed ... 99, 105
  - High Sierras ... 99, 100
  - Hog Ranch ... 105
  - Lick Observatory ... 197
  - Lines, of equal ... 197
  - Livermore ... 87, 194, 195, 197
  - Livermore Valley ... 193, 199
  - Local, vagaries of ... 194, 195
  - Modesto and Turlock districts ... 358
  - Mokelumne Hill ... 302
  - Mokelumne River ... 366
  - Mt. Hamilton ... 87, 193-195, 199
  - Nevada City ... 302
  - Niles Canyon ... 84
  - Percentage to run-off ... 88, 194-195
  - Pleasanton ... 193
  - Portolacca ... 105
  - Railroad Flat watershed ... 366
  - Records ... 99, 100, 193, 195
  - Relation to floods ... 87
  - Relation to run-off ... 87, 100, 105, 194
  - San Antonio Valley ... 88
  - San Francisco ... 80
  - Shingle Springs ... 302
  - Sierra Nevada Mountains ... 302
  - Sonora ... 302
  - Stanislaus River drainage basin ... 302
  - Stations ... 192-195, 302
  - Studies by Williams ... 197
  - Sunol ... 193
  - Tables ... 199
  - Tuolumne River Canyon ... 284
- Rain gauges—
  - Clock recording ... 193
  - High Sierras ... 99
- Rainwater, interception of ... 140
- Raising—
  - Crystal Springs dam ... 252
  - Crystal Springs upper dam ... 388
  - Portola dam ... 385
  - San Andreas dam ... 387
  - San Leandro dam ... 135, 136
- Raising of water level—
  - Hetch Hetchy Valley ... 9
  - Poopenaut Valley ... 293
- Ramsey dam ... 306
- Ramsey reservoir ... 306
- Rancheria Creek, storage on ... 58
- Rapid—
  - Growth of San Francisco ... 77
  - Response to rain, Livermore Valley ... 86, 87
  - Rise in flow after rainfall, Livermore Valley ... 86
- Rapidity of flow, Alameda Creek ... 197
- Rate—
  - Employers' liability insurance ... 298
  - Fixing, Oakland ... 177
  - Of delivery, Hetch Hetchy aqueduct tunnels ... 121, 221
  - Of discharge, flood flow ... 98
  - Of increase in population ... 76
  - Of run-off, Calaveras watershed ... 196

INDEX

Page
Rate of flow—
    Alameda Creek 190
    Coarse sands 201
    Underground waters 198
Rating table—
    Cherry Creek 379
    Eleanor Creek 377
    Tuolumne River 373
Ratio—
    Geometric, growth of cities 77
    Of mean monthly discharge, City catchments to La Grange 99
    Of mountain run-off to valley rainfall 105
    Of run-off to rainfall 99, 100
Ravenswood—
    Range of tides at 254
    Routes of filtered water supply 321, 323
Ravenswood wells 80, 96, 391-392
Raw water storage 320
Real value of Hetch Hetchy 151
Reasonable use of water—
    For irrigation 359
    Preserved to lands overlying water bearing strata 209
Reclamation—
    Marsh lands 203, 204
    Swamp lands 77
Recognition—
    Ban San Francisco of vested rights 312
    Of priorities, mass curve on 285
Reconnaissance—
    By John R. Freeman 71
    By W. C. Hammatt 290
    By Horace Ropes 109-110, 221
    Geological 109-110
    Hetch Hetchy tunnels 109, 110
    San Joaquin Valley 108
Records—
    Alameda Creek discharge 82, 84, 188
    Errors in by Spring Valley Water Co 84, 85
    Rainfall 99, 100
    Rainfall and run-off above Sunol 195
    Run-off, Spring Valley Water Co 196
    Water companies, not dependable as to yield 82
Recovery of water through pumpage 204
Recreation use of reservoir margins 38-45
Recurring heavy rains—
    Coyote River 207, 208
    Santa Clara Valley 207, 208
Red Bank crossing, Mt. Shasta aqueduct 332
Red Bluff, power plant at 328
Red Mountain bar—
    Belt of serpentine 110
    Elevation 108
    Location 116
    Roads near 281
    Water level at 108
Reduction—
    Available supply, Pleasanton wells 191
    Freight rates, through Panama Canal 231
    Taxes 166
Redwood City—
    City Council 163
    Interest in Hetch Hetchy 163
Redwood gatehouse, pipe line from 294
Redwood tunnel—
    Cost of 252, 253
    Diameter 244
    Length 244
    Location 252
    Unit costs 244, 246, 252, 253
Refill, Livermore Valley, composition of 201
Refilling depleted reservoirs 294
Refusal by Spring Valley—
    To extend mains 213, 214
    To install larger mains 213-218
Regulation—
    Outflow, gravel, deposits, Livermore 196

Page
Regulation—
    Of outflow, gravel deposits, Pleasanton 196
    Of run-off 186
Regulations—
    Enforcing of 34
    By superintendent of park 55
    Formulating of 34
    For sanitary control of water supply 34
    Yosemite National Park 34, 54
Regulators, Stanislaus River reservoir sites 303
Reimbursement to San Francisco by D. P. Doak of moneys expended on Hetch Hetchy 328-329
Relation—
    Floods to rainfall 87
    Precipitation to run-off 98
    Rainfall to run-off 105
    Run-off to rainfall 87, 194
Release of irrigation priorities
    Actual less than theoretic 104
    At Poopenaut reservoir 293
    Below Moccasin Creek power-house 61, 101
    From Hetch Hetchy reservoir 121
    In Colorado 83
    Measurement of 33
Reliability—
    Of discharge, McCloud River 330
    Of estimates based on insufficient data 99
    Of service, McCloud River project 331
Relief by courts to shortage of water for residents 188
Relief dam 306
Relief map—
    Lands and rights of Spring Valley Water Co 394
    Tuolumne River 4
Relief reservoir 303, 305, 306
Remedy at law, injury to rights to percolating waters 205
Remoteness, McCloud River 331
Rents Spring Valley Water Co 385
Repairs—
    Hetch Hetchy camp 286, 287
    Hetch Hetchy dam plant 288
    Poopenaut dam plant 291
    Poopenaut camp 291
    To pipe, accessibility for 258
    To submarine pipe lines 127
Replenishment—
    Artesian strata, Coyote Valley 209
    Artesian strata, Santa Clara Valley 208, 209
    By melting snows 11, 13
    Cones 173
    Hetch Hetchy reservoir 11, 13, 25
    Niles Cone 91, 94, 204
    Subterranean reservoir, Alameda Creek gravel 198
    Wapama Falls by dam at Vernon Lake 58
Reports—
    American-Cosumnes project, by J. H. Dockweiler 311-314
    Doctrine of percolating waters, by Percy V. Long 205-210
    East Bay region, by J. H. Dockweiler 173-178
    Eel River project, by C. E. Grunsky 345, 346
    Feather River project, by C. E. Grunsky 347-354
    Filtered water supply, by Allen Hazen 315-325
    Metropolitan water district, San Francisco, by Percy V. Long 161-166
    Modesto and Turlock Irrigation Districts, by J. H. Dockweiler 357-363
    Mokelumne River project, by C. E. Grunsky 365-372
    Niles Cone, by J. H. Dockweiler 203, 204
    Quality of Tuolumne River water, by Allen Hazen 53-57
    Stanislaus River project, by C. E. Grunsky 303-309
    Yuba River, by C. E. Grunsky 355, 356
Requirements, Bay cities and communities 21, 357
Reservation—
    Of unappropriated Tuolumne River water for use of Bay cities 22
    To City of reservoir sites above Hetch Hetchy 28
Reserve—
    Storage 28, 68, 126
    Supply 58

Page

- Reserves—
  - Against accidents 65-68, 129, 134
  - Of Peoples Water Co. exaggerated 82
  - Of Spring Valley Water Co., exaggerated 82
- Reservoirs—
  - Boston 35-42
  - Camping upstream from 36
  - Covered for mountain supply 129
  - Depletion of 104
  - England 46-47
  - Enhance beauty of landscapes 51
  - Fishing upstream from 36
  - Forbidding of bathing in 34
  - In Catskill Mountains 44, 145
  - In foothills 58
  - In metropolitan parks 38
  - In populous communities 35, 38
  - Modesto and Turlock Districts 83
  - Partial emptiness of 187
  - Pleasure boats on 49
  - Scotland 48-50
  - Tourist routes round 43, 46-51
- Reservoir sites—
  - Above Hetch Hetchy 28
  - Absence of on Sierra rivers 151
  - American-Cosumnes project 312, 314
  - Mokelumne River 160a, 366, 367
  - Necessity of on Sierra rivers 160k
  - Owned by City 138
  - Stanislaus River 303-4, 306
  - Strawberry Creek 303, 304
- Resistance to corrosion, steel pipe 229
- Resolutions on Hetch Hetchy—
  - Berkeley City Council 161-162
  - Daly City Board of Trustees 164
  - Oakland City Council 162, 163
  - Palo Alto City Council 163, 164
  - San Jose City Council 163, 164
- Resources of water companies overestimated 69, 70
- Restrictions—
  - Found needful by sanitary science 33
  - Sanitary, proposed by City 34
- Retarding building up of San Francisco, by inadequate water supply 220
- Retarding effect—
  - Moss-like growth in tunnels 221
  - Of eddies, etc. 82
  - Of great conflagration 78
- Return water 204, 357
- Revenue—
  - Peoples Water Co. 177
  - Spring Valley Water Co. 385
- Rich Gulch 366-369
- Richmond District, San Francisco—
  - Complaints of inadequate water supply 211, 213, 214
  - Inadequate fire protection 213, 214, 220
  - Inadequate water pressure 213, 214
  - Views of 213, 214
- Richmond—
  - Wells, yield from 172, 177
- Richness, concrete, Hetch Hetchy dam 287
- Right of owner to accustomed flood flow of stream paramount to appropriator's 208
- Rights—
  - Bay Cities Water Co 179, 187
  - Claimed by Doak 341
  - La Grange Water and Power Co 285
  - Modesto Irrigation District 285
  - Niles Cone 179
  - Owners of artesian wells 205, 208
  - Owners of superimposed lands 208
  - Spring Valley Water Co 384, 385
  - To percolating waters 94, 205
  - Turlock Irrigation District 285
  - United Properties Co 179

Page

- Rights of way—
  - Desired by City 15, 22
  - Early intake 22
  - Filtered water supply 325
  - For roads 15
  - Hetch Hetchy aqueduct, divisions 72, 300, 301
  - Power house No. 2, Hetch Hetchy 22
  - Sacramento River project 325
  - San Joaquin River project 325
  - Securing of 72
  - Sierra Blue Lakes Water & Power Co 368-370
  - Spring Valley Water Co 394
  - Stanislaus River project 308
- Rights, prior—
  - American River 312
  - Bay Cities Water Co 187
  - Cosumnes River 312
  - McCloud River 341-342
  - Modesto and Turlock Districts 21, 33, 83, 358
  - Mokelumne River 366
  - Sacramento River 342
  - Stanislaus River 303, 304, 305
  - Tuolumne River 8, 285, 293
  - Yuba River 355
- Rigidity, steel pipe 229
- Rio Vista intake 319, 324
- Rio Vista pipe line 324
- Rio Vista pumping station 319, 324
- Riparian rights—
  - Alameda Creek 180
  - McCloud River 341
  - Owned by Spring Valley Water Co 384, 385, 394
- Rise—
  - Of ground water, irrigation districts 358
  - Of water table 357
- Risk of typhoid 37
- River crossings 320
- River waters—
  - Hardness of 316
  - Solids in 316
  - Treatment of 317
- Riveted pipe—
  - McCloud River project 337, 338
  - Mokelumne River project 369
  - Stanislaus River project 308
- Riveting costs—
  - Bay head pipe 236
  - Los Angeles pipe 230, 232
  - Portland aqueduct pipe 237
- Roads—
  - Around reservoirs 35, 51
  - Beds 13, 15
  - Building, Hetch Hetchy project 13, 15, 240, 281, 298
  - Built by D. P. Doak 339
  - Catchment areas 35-45
  - Chinese Camp to Groveland 289
  - Chinese Camp to Hog Ranch 289
  - Construction costs, Hetch Hetchy project 300, 301
  - Crystal Springs dam 388
  - Date for building 72
  - Difficulties in building 72
  - Early intake 282
  - Expenditures on 72
  - Grades of 72
  - Hetch Hetchy, scenic 10, 11, 12
  - Hetch Hetchy, wagon 13, 15
  - Into Tilltill Valley 15, 23, 290
  - Maintenance of 13, 72
  - Moccasin to Big Creek 289
  - Near Red Mountain Bar 281
  - Near shaft sites 265
  - Norway 17, 18
  - Open to public 13
  - Poopenaut dam 293
  - Public lands for 15, 29
  - Railroad rails on 13

INDEX

Page

- Roads—
  - Rights of way for 15
  - Rosasco to Hetch Hetchy 290
  - Routes of 11, 13, 15
  - Surveys of 72
  - To be constructed at City's expense 13
  - To Lake Vernon 23
- Roberts, Mrs. G. C., complaint of inadequate water supply 216
- Robinson's Valley 307
- Rock—
  - Insolubility of 53
  - Tunneling of 71
- Rock, character of—
  - Elizabeth tunnel 223
  - Los Angeles aqueduct tunnels 224, 225
- Rock formation—
  - Canyon tunnel 284
  - Hetch Hetchy aqueduct 276
  - Tesla tunnel 281, 283
- Rocks—
  - Chabot line 124, 125
  - Decomposition of 124
  - Jointing of 276
  - Peninsula line 124, 125
  - To be encountered, Hetch Hetchy aqueduct 111
- Rolph, James, Jr., letter to Advisory Board 5
- Ropes, Horace—
  - Charge of construction of Boston aqueduct tunnels 221
  - Commendation for zeal in City's service 160s
  - Cost estimate, Hetch Hetchy project 239-301
  - Reconnaissances by, Hetch Hetchy project 109, 110, 221
  - Studies for New York aqueducts 221
- Rosasco—
  - Cost of cement delivered 242
  - Railroad to Hetch Hetchy 290
  - Road to Hetch Hetchy 290
  - Station on Sierra Railway 289
- Rough and Ready Creek mouth, wood-stave pipe at 260
- Roughness—
  - Co-efficients of Hetch Hetchy aqueduct tunnels 221, 222
  - Of finish, tunnels 221
- Roundout Creek 145
- Rule of common law, applicable to percolating waters 209
- Rules, Yosemite National Park 34, 54
- Rulings, Supreme Court, use of percolating waters 205-210
- Run-off—
  - Alameda Creek 91, 190, 194, 195, 197
  - American-Cosumnes project 313
  - Arroyo Mocho 196
  - Arroyo Valle 193, 196
  - Atmospheric moisture, effect on 194
  - Calaveras damsite 193
  - Calaveras watershed 196
  - Cherry Creek 380, 381
  - Cherry Creek watershed 98, 99, 101-103, 105
  - Data, lack of 88
  - Eleanor Creek 377-379
  - Eleanor watershed 98, 99, 101-103, 105
  - Falls Creek 375, 376
  - Feather River 348
  - Hetch Hetchy watershed 98, 99, 101-103, 105
  - Hog Ranch 105
  - McCloud River 329
  - Mokelumne River 366
  - Nashua River 36
  - Portolacca 105
  - Railroad Flat watershed 366
  - Records 195, 196
  - Regulation of 186
  - Relation to precipitation 98, 100
  - Relation to rainfall 87, 88, 100, 105, 194-195, 197
  - San Antonio Creek 193
  - Streams tributary to Sacramento Valley 329
  - Sunol watershed 196
  - Temperature, effect on 194
  - Tuolumne River 98, 99, 101-103, 105, 374-376
- Rural—
  - Communities, growth in population of. 78
  - Population, increase of 77
- Russian River, water dropped into from Eel River. 345
- Rusting of steel pipes, preservation from 21
- Rustproofing steel pipe 229
- Rust, resistance of 229

- Sacks for cement, charge for 241, 242
- Sacramento River—
  - Adverse rights 342
  - Brackish water 317
  - Cities and towns on 317
  - Crossings 324, 327, 337
  - Dikes 77
  - Filtering water from 160g
  - Flow 317, 340
  - Navigability of 317, 336, 340
  - Swamp lands 77
  - Tide flows 317
  - Water 56, 57, 316, 317
- Sacramento River project—
  - Bay crossing 320, 321
  - Capacity 315
  - Cost estimates 324, 325
  - Cost of operation 325
  - Crossings 320, 321, 322, 323
  - Disadvantages of 160g
  - Filter plants 319, 320
  - Goat Island route 322
  - Intake position 315, 317
  - Livermore pass route 323
  - Oakland reservoir 320
  - Pipe line 319
  - Pumping stations 319, 320, 321
  - Ravenswood route 323
  - Raw water storage 320
  - Rights of way required for 325
  - San Pablo route 322
  - Steel pipe 320
  - Tunnels 320, 321
- Sacramento Valley—
  - Area of 329
  - Industries in 313
  - Irrigable lands 313
  - Irrigation requirements 329
  - Run-off, streams in 329
- Sacramento Valley Irrigation Co. 336, 340
- Saddle reservoir 131
- Safeguards—
  - Against interruption, Boston water supply 38
  - Against shortage of water 64
  - In Calaveras reservoir 64
- Safe supply—
  - Alameda Creek 190
  - Peninsula reservoirs 388
- Safety—
  - Against accident, Freeman plan 144
  - Against earthquakes 126, 127
  - Of water 54
- Salinity of water 315
- Sale—
  - Diversion of water for 266, 267
  - Of water, Coyote River, at distance 209
- Sales of water, Spring Valley Water Co. 385
- Saltiness of water 70, 175
- Salt Lake City, consumption per capita 79
- Salt marshes—
  - Bay head pipe 232, 234
  - Niles Cone 203
- Salt River project tunnels 250
- Salt water—
  - Back flow of 80, 81
  - Distance extending up stream 314
  - Infiltration of 80
- San Andreas dam 387
- San Andreas fault 223, 253

Page
San Andreas Junction 297
San Andreas reservoir..........65, 131, 294, 297, 387
San Andreas tunnel 246, 249, 297
San Andreas watershed, care of water at.......... 61
San Antonio Creek—
  Gaugings 193
  No dependable data as to discharge.......... 88
  Run-off 193
  Valley 88
  Watershed 186
San Antonio dam—
  Cost 259
  Effect on Niles Cone.......... 81
  Elevation of 257
  Hydraulic fill 257, 259
  Height 257, 259
  Method of construction 257
  Plan of 257
  Prudence of building 68, 69
  Roadway across 257
  Section of 257
San Antonio damsite.......... 186, 257
San Antonio pipe line 230
San Antonio reservoir—
  Advisability of building..........88, 94, 97, 190, 192
  Area of 256
  Catchment area 84
  Cost of 259
  Elevations 256
  Evaporation 84, 189, 199
  Flow line 256
  Gravity flow of water from.......... 122
  Lack of data on run-off from.......... 88
  Levels 256
  Location of 112, 256
  Plan of 257
  Property of Spring Valley Water Co. at.......... 256
  Storage capacity 67, 197, 256
  Temperature 84
San Antonio tunnel 246, 258
San Bruno sandstone 124. 125, 244, 246, 252
San Bruno tunnel 238, 246, 249, 295, 296
Sand—
  Cost 243, 288
  Filtration 34, 317
  From public lands for construction work.......... 15, 22
  Proportion in concrete.......... 287, 288
Sand Flat 303, 306
San Diego, consumption per capita.......... 79
Sands—
  Coarse, rate of flow through.......... 201
  Livermore Valley, voids in.......... 199
  Niles Cone 89, 90, 91
Sandstones 111, 225,246-249, 255, 258, 264. 265, 291
Sandstone tunnels, Los Angeles aqueduct.......... 223
San Fernando reservoir 128
San Francisco—
  Advantageous location of 78
  Area of 303
  Areas not supplied with Spring Valley water.......... 212
  Building up retarded by inadequate water supply.......... 220
  City distributing system 211, 212, 384
  Climate 79
  Commercial center 77
  Consumption of water 79
  Density of population.......... 78
  Distance across 321
  Factory population 77
  Fault lines in neighborhood of.......... 321
  Future demands for water 78
  Future population 78
  Growth 76, 77
  Harbor 78
  History of development of water supply.......... 386-390
  Inadequate water supply 211-220
  Increase in population 78

Page
San Francisco—
  Lack of lawns and gardens.......... 79
  Litigation with Spring Valley Water Co.......... 393, 394
  Location of 383
  Opportunities for 138
  Ownership in Hetch Hetchy Valley.......... 13
  Percentage built up 383
  Population 78
  Quantity of water available for....305, 311, 313, 314, 328, 348
  Rainfall 80
  Service areas 212
  Service connections 384
  Topography 211, 383
  Water supply problems 80
  Wells 383
  Zones 211, 212, 384
San Francisco Bay—
  Bridge across 166
  Communities on 9, 76
  Crossings 127
  Depth of water 127, 321
  Distance from shore to shore.......... 127
  Tide range 254
  Tunnel under 321
San Francisco Bay cities.......... 22, 71
San Francisco Bay communities.......... 77, 165
San Francisco Bay municipalities.......... 161-165
San Francisco Bay shore, wells on 82
San Francisco City Water Works.......... 385, 386
San Francisco District—
  Increases in population 76, 312
  Population 312
  Water supply, needs of.......... 80
San Francisco Fire Department, reports on inadequate fire protection 211, 218. 219
San Francisco Gas and Electric Co., rights on Mokelumne River 367
San Francisco Metropolitan Water District 144
San Francisquito Creek 389
Sanitary—
  Control 32
  Difficulties 309
  Necessity for filtration 158
  Precaution by storage 260, 309, 343, 350
  Regulations 34, 36, 55
  Restrictions 32-34, 36, 54-55
  Safeguard through storage 260, 309, 343, 350
  Safety through storage 260, 309, 343, 350
  Safety of water 54
  Survey, Hetch Hetchy and Lake Eleanor.......... 53-55
San Gregorio Creek 81, 96
San Joaquin—
  Aqueduct 160h
  Irrigation district 305
  Pipe 229, 230-236, 269, 270
San Joaquin pipe line—
  American-Cosumnes project 313
  Freeman plan 139-141
  Grunsky plan 139, 141
  Hetch Hetchy project..........229-231, 262, 263, 269, 270
  Manson plan 139
San Joaquin River—
  Bottom lands 270
  Brackish water 317
  Cities and towns on.......... 317
  Crossings 114, 122, 266-268, 269, 270, 308. 324
  Dikes 77
  Elevations 266-268
  Formations 111, 114, 115
  Freshets 269
  Line of flow 114, 115
  Marsh lands 122
  Navigation 317
  Overflow lands 270
  Sloughs 267, 268
  Tide flows 317
  Water 56, 316-317

Page

- San Joaquin River—
  - Water levels 266-268
- San Joaquin River project—
  - Bay crossing 320, 321
  - Capacity 315
  - Chabot Lake route 322
  - Cost estimates 324, 325
  - Cost of operation 325
  - Filter plants 319
  - Livermore Pass route 323
  - Oakland reservoir 320
  - Pumping stations 319, 320, 321
  - Ravenswood route 323
- San Joaquin Valley—
  - Equalizing basin 265
  - Crossing 139, 141
  - Irrigation tracts 305
  - Levels 108, 261-263, 266-268
  - Pliocene formation 265
  - Railroads 231
  - Reconnaissance 108
  - Semi-arid surface 229
  - Shafts sunk in 265
  - Surge tank 265
  - Surveys by Grunsky 108
  - Topography 108, 261-263, 266-268
- San Jose—
  - Branch aqueduct toward 123, 255
  - City Council 163
  - Location 163
  - Population 163
  - Resolution on Hetch Hetchy 163
- San Leandro Cone—
  - Agricultural needs of water 97
  - Area 174, 175
  - Draft on 173, 175
  - Location of 174
  - Replenishment of 173, 175
  - Source of supply 174
- San Leandro Creek 97, 112
- San Leandro dam—
  - Cost of enlarging 134
  - Enlargement of 67, 68, 134, 135, 136
  - Safety of 134
  - Views 66
- San Leandro reservoir 134, 172, 177
- San Leandro reservoir, upper 176
- San Lorenzo Cone—
  - Area 174-175
  - Draft on 173
  - Location of 174
  - Replenishment of 173
  - Source of supply 174
- San Lorenzo Creek siphon 291
- San Lorenzo Water Company 174, 178, 203
- San Mateo 123, 164
- San Mateo County 76, 78, 163
- San Mateo Creek 294
- San Mateo tunnel 123
- San Mateo Waterworks 385, 388
- San Miguel dam 129, 297
- San Miguel dam site 132
- San Miguel-Millbrae Division 240, 295-296-297, 301
- San Miguel reservoir—
  - Area covered by water surface 129
  - Delivery of Hetch Hetchy water to 294
  - Diagram 132
  - Elevation 129, 131-132
  - Flow line 129-130, 133
  - Gravity flow from Hetch Hetchy 129
  - Location of 63, 129
  - Profiles 132
  - Storage capacity 62, 129, 131-132
  - Survey 129
  - Views 130, 133
- San Miguel reservoir site 129

Page

- San Miguel tunnel 246, 249
- San Pablo Cone
  - Area 174-175
  - Draft on 173, 175
  - Example of 176
  - Location of 174
  - Lowering of water table 176
  - Replenishment of 173, 175
  - Source of supply 174
  - Wells 176-177
- San Pablo Creek 176
- San Pablo route, filtered water supply 318, 322-323
- San Pablo reservoir 176
- San Pablo wells 172, 176-177
- San Ramon Valley 201
- Santa Ana Canal tunnels 250
- Santa Clara County 78
- Santa Clara Valley—
  - Area of irrigable lands 392
  - Artesian waters 206
  - Communities in 76
  - Crossed by bay head pipe 253
  - Depletion of artesian strata 209
  - Depth of irrigation 78
  - Draft on 209
  - Duty of water 392
  - Formation of 207
  - Gorges 206-207
  - Gravels 207-210, 253
  - Increase in population 209
  - Landowners' demands 208
  - Percolation of water into underlying strata 208
  - Recurring heavy rains 207-208
  - Replenishment of artesian strata 208-209
  - Subterranean channels underlying 207
  - Wells 208-209
- Santa Fe Railroad 176
- Santa Margarita sandstones 111-114, 124-125, 247, 249, 258, 259, 260, 264-265, 291
- Satisfaction of priorities—
  - American-Cosumnes project 312
  - Tuolumne River project 285
- Saturation—
  - Fluctuation of plane of 198
  - Livermore gravels 259
  - Plane of, Niles Cone 70, 80
  - Sunol gravels 259
  - With percolating water 205
- Saugus Division, Los Angeles aqueduct 128, 224, 227
- Sausalito Water and Steam Tug Company 385
- Saving—
  - Deferred construction Moccasin Peak tunnel 260
  - Hetch Hetch aqueduct 127
  - Millbrae-San Mateo Division 297
  - San Miguel-Millbrae Division 297
- Stanislaus River project, by reduction in tunnel capacities 308
- Steel pipe, through cement lining 229
- Scant run-off 91
- Scenery, Hetch Hetchy Valley 6, 10, 12, 15-17, 19, 57, 148
- Scenic road, Hetch Hetchy—
  - Arcades on 18
  - Branch to Tilltill Valley 290
  - Cost of 290
  - Grades on 15
  - Length of 241, 290
  - Map showing 11
  - Route of 11
  - Time of building 74
  - Type of construction 19
  - Views 10, 12
- Schell ditch 307
- School census, San Francisco 77
- Schussler, H —
  - Additional supply 68
  - Affidavits of 192
  - Criticism of his Alameda Creek yield estimates 84, 180-201
  - Development of underground storage, Livermore Valley 86, 88

Page

Schussler, H.—
  Durability of his wrought iron pipe ... 122
  Floods, Niles Cone ... 83
  Gaugings, Niles Canyon ... 83
  Increase in population ... 76, 78
  Isohyetal lines ... 197
  Monographs by ... 192
  Rainfall charts ... 197
  Scoharie Creek ... 145
Scope of preliminary studies ... 71
Scotland, reservoirs in ... 48-50
Scowden, report on Calaveras ... 388
Scrapers, use of ... 233-234
Screenhouse, Early Intake ... 284
Screening of surface waters ... 61
Screens—
  Cherry Valley reservoir ... 289
  Early Intake ... 282, 284
  Eleanor reservoir ... 289
Sea level, fall of ground water below ... 70, 176
Searsville—
  Dam ... 385
  Reservoir ... 385, 389
Seasonal—
  Distribution of rainfall, Livermore Valley ... 201
  Rainfall, Sierra Nevada Mountains ... 302
  Variation, Sacramento River water ... 317
  Variation, San Joaquin River water ... 317
Season, working, Hetch Hetchy region ... 73-74
Seattle—
  Mountain source owned by ... 138, 147
  Progressive development ... 153
  Sanitary restrictions ... 33
Sea water spoiling wells ... 176
Secondary uses of water ... 21
Second Garotte, shaft at ... 284
Secretary of Interior—
  Interview with ... 7
  Order to show cause ... 7, 312
Section corners hard to locate ... 108
Sections—
  Alameda Creek floods ... 87
  Alternative distribution aqueducts ... 125
  Cherry Valley ... 8
  Crystal Springs by-pass ... 238
  Dam sites ... 8
  East bay region sources of supply ... 172
  Eleanor Valley ... 8
  Hetch Hetchy aqueduct ... 112-117
  Hetch Hetchy aqueduct tunnels ... 120
  Hetch Hetchy dam ... 118, 285
  Hetch Hetchy Valley ... 8, 146
  Livermore Valley wells ... 89
  Moccasin Creek power station ... 280
  Niles dam ... 181
  Poopenaut dam ... 293
  San Antonio dam ... 257
  San Bruno tunnel ... 238
  San Leandro dam enlargement ... 135
  Sunol dam ... 184
Sedimentary rocks ... 255, 259, 264
Sedimentation—
  Purification by ... 38
  Stanislaus River water ... 309
Seepage—
  Alameda Creek ... 199-200
  Merced Lake ... 126
  Modesto and Turlock Irrigation Districts ... 358
  Niles Cone ... 94
  San Joaquin Valley tunnels ... 265
Seismicity, region of ... 110
Semi-arid lands—
  Great stretches of ... 209
  Necessity of water for ... 80
  San Joaquin Valley ... 229
  Water supplies in ... 179

Page

Sentiment strong in favor of Greater San Francisco movement. 166
Septic tanks ... 34
Serpentine formation ... 111, 116, 124-125, 247-249, 259, 264, 279, 291
Service areas—
  Peoples Water Company ... 177
  San Francisco ... 212
Services—
  Hayward ... 178
  Hercules Water Company ... 177
  Oakland Division ... 176
  Peoples Water Company ... 177
  San Lorenzo Water Company ... 178
  Spring Valley Water Company ... 384
  Union Water Company ... 177-178
Service zones, San Francisco ... 211-212
Servitude, establishing of ... 34
Settlement of ground, strain due to ... 229
Sewage pollution—
  Sacramento River water ... 317
  San Joaquin River water ... 317
Sewerage—
  Appliances, installation of ... 34
  Disposal, Hetch Hetchy camp ... 286
  Regulation of ... 55
Sewer System, McCloud ... 335
Sewer system on catchment areas ... 43, 54
Shafts ... 251-252, 255, 259-260, 265, 269,283-284, 289, 291, 297
Shaft sites ... 260, 265
Shallow flowage ... 304, 307
Shasta National Forest Reserve ... 331, 336
Sheet steel pipe, east bay region ... 177
Shepard Canyon, yield ... 177
Shift bosses' wages ... 223
Shifts worked, Los Angeles aqueduct tunnels ... 223
Sherman Island ... 319
Shingle Springs, rainfall ... 302
Shipping—
  Canned fruits and asparagus ... 77
  Los Angeles pipe ... 230
  Steel for Hetch Hetchy pipe, via Panama Canal ... 231
Shop buildings, Hetch Hetchy ... 287
Shores, Hetch Hetchy reservoir ... 13
Shortage of water—
  Disaster consequent upon ... 188
  Niles Cone ... 91, 94 188
  San Francisco ... 64, 211-220
Shortage, storage capacity, Tuolumne River reservoir sites ... 58
Shoshone dam ... 119
Shrinkage—
  In flow, Alameda Creek ... 86, 198
  Of available supply of Oakland ... 94
Sidings, railroad, Rosasco to Hetch Hetchy ... 290
Sierra and San Francisco Power Company ... 304-305-306
Sierra Blue Lakes Water and Power Company ... 160b-160d 365-370
Sierra Club excursion to Hetch Hetchy ... 60
Sierra Nevada region—
  Haulage rates in ... 242
  Necessity of storage reservoirs ... 160k
  Rainfall ... 302
Sierra Point tunnel ... 251
Sierra Railroad ... 115-116. 289
Signboards cautioning against pollution of reservoirs ... 36, 38, 39 41
Silt—
  Clogging of gravel conduit ... 200
  Deposited over gravel ... 88
  Detention in natural filter ... 200
Silting—
  Of gravels ... 191
  Of San Leandro reservoir ... 65, 134
Silver Lake ... 310
Silver Valley ... 304
Silver Valley dam ... 306
Silver Valley reservoir ... 304-306
Sinking of waters—
  In Coyote River ... 206
  Into Alameda Creek gravels ... 196

INDEX

Page

- Sinking of waters—
  - Into Arroyo Mocho gravels 199-200
  - Into Arroyo Valle gravels 199, 201
  - Into Coyote Valley gravels 207
  - Into Santa Clara Valley gravels 207-208
- Siphon joints 232
- Siphons—
  - Alameda Creek 258, 291
  - Bear Gulch 139, 141
  - Dry Creek tunnel 278
  - Freeman plan 139-140
  - Grunsky plan 139-141
  - Hetch Hetchy aqueduct 21, 121, 128
  - Los Angeles aqueduct 128, 139, 230-234
  - Moccasin Creek 139, 141
  - New York aqueduct 122, 229, 232
  - San Lorenzo Creek 291
- Six Mile Bar 307
- Sizes of water mains, San Francisco 213-217
- Skaneateles, Lake 53
- Sketch—
  - Castro Valley dike 136
  - San Leandro dam enlargement 135-136
- Slope—
  - Of tunnels, Hetch Hetchy aqueduct 121
  - Of water table 94
- Sloughs—
  - Bay head pipe 253
  - San Joaquin River 267-268
- Small increase in future yield from present sources 81
- Smith Creek 96, 187
- Smith's Peak 15, 59-60
- Snowfall—
  - Cherry Creek watershed 99
  - Eleanor Creek watershed 28, 99
  - Hetch Hetchy watershed 24, 99
  - High Sierras 99-100
  - Measurement of 101
  - Railroad Flat watershed 366
- Snow Mountain Water and Power Company 345
- Snows, melting of—
  - Dates of 98
  - Cherry Creek watershed 105
  - Eleanor watershed 105
  - Hetch Hetchy watershed 105
  - Replenishment by 11, 13
- Snow Valley dam 160a
- Snow Valley reservoir 160a
- Soaking in of waters, Pleasanton Valley 86
- Softness of water—
  - American River 153
  - Hetch Hetchy 56, 69, 138, 153
  - Mokelumne River 153
  - Sacramento River 317
  - Stanislaus River 153
  - Tuolumne River 151, 153
  - Whipple on 153
- Softness, steel pipe, San Joaquin Valley 229
- Soil—
  - Conditions, Modesto and Turlock Districts 358
  - Depth of cover, High Sierras 100
  - Purifying power of 54
  - Studies by J. C. Branner 111, 124-125
  - Survey, Livermore area 85
- Soils—
  - Encountered on Chabot and peninsula lines 124
  - Encountered on line of Hetch Hetchy aqueduct 110-111
  - Livermore Valley 89-90
- Soledad Canyon 230-234
- Solids in river waters 316
- Solution of water problem—
  - Los Angeles 80, 138
  - New York 138
  - San Francisco 80
- Sommersville, water supply of 305
- Sonora—
  - Rainfall 302

Page

- Sonora—
  - Supplied by Phoenix reservoir 305
- Soulsbyville, water supply of 304
- Sources of supply—
  - Abandonment of 80
  - Bay shore ground waters 91
  - Boston 36
  - Comparison of 156-157
  - Investigations 70
  - Local 71
  - Niles Cone 70, 91, 191-192
  - Peninsula 81
  - Peoples Water Company 172, 177
  - Present yield of 80
  - Spring Valley Water Company 383
  - Union Water Company 177
  - Western slope of peninsula 81
- South Fork—
  - Mokelumne River 366-367
  - Stanislaus River 303-304, 306
- South Fork, Tuolumne River
  - Canyon crossing 283
  - Elevation at mouth 109
  - Power station at 143
  - Water level at mouth 109
- South of Army Street Improvement Association, complaint on inadequate water supply 216
- South San Francisco District, no mains for fire protection 220
- South San Joaquin Irrigation District 223, 276, 303, 307
- Southern Alabama Street and Vicinity Improvement Club, complaint on inadequacy of water supply 216
- Southern Pacific Company—
  - Bay shore tunnels 251
  - Contract prices for mountain work 251
  - Rate paid for common labor 252
  - Sierra tunnels 250
- South Yuba River, gaugings 101
- Spaulding Lake, dam at 119
- Specification—
  - Steel pipe, Feather River project 350
  - Steel pipe, Los Angeles aqueduct 230
- Speculative nature of D. P. Doak's proposition 342
- Speed of construction, Canyon tunnel 286
- Spill crest—
  - Cherry Valley dam 26
  - Early Intake dam 285
  - Eleanor dam 27
  - Hetch Hetchy dam 288
  - Poopenaut dam 291
- Spillway—
  - Hetch Hetchy dam 285
  - Poopenaut dam 293
  - San Antonio dam 285
- Spot Pond reservoir 36, 147
- Springfield aqueduct 229
- Spring Valley Water Company—
  - Additional supply 80, 83, 94, 97
  - Alameda Creek system 383, 388
  - Areas of lands owned by 385, 392
  - Borings by 188-189
  - Calaveras purchase 385, 388
  - Capitalization 385
  - City distributing reservoirs 131, 384
  - City distributing system not essential to Hetch Hetchy project 62
  - City pipe system 131, 384
  - Companies acquired by 385
  - Condemnation of 62
  - Courtesy of 81
  - Data furnished by 81
  - Date of incorporation 385
  - Delivery conduits 383-384
  - Depreciation 385
  - Disbursements 385
  - Diversions from Alameda Creek 175, 204
  - Errors in records 84-85, 180
  - Extensions of mains 213-218

Page

- Spring Valley Water Company—
  - Franchises 393
  - Friction joints 232
  - Gaugings by 83-84, 186
  - Inadequacy of mains 211
  - Inadequacy of supply 211-220
  - Income 385
  - Increase in supply 69-70
  - Lands owned by 96, 186, 256, 384-385, 394
  - Litigation over diversions 91
  - Litigation with City 393-394
  - Litigation with Clough 85, 94
  - Mains supplying outlying districts 212
  - Meters 384
  - Monoply held by 384
  - Negotiations for purchase 62-63, 144, 394-400
  - Niles Cone, drafts on 80, 91
  - Operation expenses 385
  - Outside sales of water 385
  - Partial ownership of watershed lands 391
  - Peninsula system 383
  - Protection of catchment areas 138
  - Pumping plants 131, 384
  - Purchase of San Mateo Water Works 388
  - Purchases to prevent competition 384
  - Records 84-85, 189, 198
  - Rents 385
  - Reserves exaggerated 82
  - Reservoirs 383, 387-390
  - Revenue 385
  - Rights of way 384-385
  - Riparian rights 384-385
  - Run-off 196
  - Sales of water 385
  - Service connections 384
  - Sources of supply 383, 391-392
  - Subsidiary companies 385
  - Taxes 385
  - Transfer from Spring Valley Water Works 385
  - Undeveloped resources 197
  - Valuation of properties 394
  - Water 61-62, 67, 138, 317
  - Watersheds 138, 391-392
  - Yielding capacity 81
- Squaw Creek 334
- St. Louis, consumption per capita 79
- Stairway, Hetch Hetchy dam 118
- Standard Canal 365
- Standard Oil Company, wells of 176
- Standard screw pipe, east bay region 177
- Standing water purifies itself 32
- Stanford Heights, no mains for fire protection 219
- Stanislaus and San Joaquin Water Company 307
- Stanislaus National Forest Reserve 303
- Stanislaus River—
  - Availability of 303
  - Diversion point 305
  - Flow 303, 305, 307
  - Inadequacy of supply 303
  - Irrigation requirements 305, 307
  - Log dams 304
  - Middle Fork 303, 306
  - North Fork 303-306
  - Pollution dangers 303-304, 307
  - Priorities 303-305
  - Quantity of water available for City 305, 307
  - Rainfall 302
  - Reservoir sites 303-304, 307
  - Source of 303
  - South Fork 303-304, 306
  - Surplus waters 307
  - Water 309
  - Watershed 302-303, 305, 306
  - Water used in Tuolumne drainage basin 304-305
- Stanislaus River project—
  - Auxiliary supply 303, 308

Page

- Stanislaus River project—
  - Bay crossing 308
  - Capacity 308
  - Comparison with Tuolumne 158-160
  - Cost of 308
  - Disadvantages of 308-309
  - Power development 305, 308
  - Pumping stations 308
  - Report by C. E. Grunsky 303-309
  - Riveted pipe 308
  - Saving by reducing tunnel capacities 308
  - Storage reservoir 309
  - Submerged pipe 308
  - Trestles 308
  - Tunnels 308
- State Constitution, amendments to 165
- State Engineering Department—
  - Discharge, Mokelumne River 365
  - Flow, Stanislaus River 307
  - Price paid for cement 241
- State Harbor Board, price paid for cement 241
- Statistics, Peoples Water Company 177
- Steel—
  - Corrosive action of peat upon 319
  - Cost of, Los Angeles aqueduct 231
  - Manufacturers, inquiries of 231
  - Protection against rust 229
  - Specification, Los Angeles pipe 230
- Steel pipe—
  - Alameda Creek Valley crossing 258
  - Adoption of cheapest structural methods through 229
  - Bay head crossing 253
  - Bursting pressure 229
  - Coating with cement 229
  - Cheaper than wrought iron 229
  - Concrete lining 229
  - Corrosion 229
  - Cost 231
  - Cradles for 229
  - Dry Creek crossing 278
  - Durability 122
  - Feather River project 350-351
  - Guadalupe Valley 296
  - Hetch Hetchy aqueduct 20, 74, 112-115, 231
  - Lining with concrete 21, 229
  - Los Angeles aqueduct 229
  - Maximum efficiency 229
  - Method of construction 229
  - Millbrae pumping station 296
  - Mission Pass tunnel 255
  - Mokelumne River project 368-369, 371-372
  - New York aqueduct 229
  - Pitting 229
  - Pittsburgh aqueduct 229
  - Portland aqueduct 229, 237
  - Potrero tunnel 296
  - Power development projects 229
  - Preservation from rusting of 21
  - Prevention of flattening 229
  - Protection of exterior 229-230
  - Rigidity 229
  - Rustproofing 229
  - Sacramento River project 320
  - San Bruno tunnel 295
  - San Joaquin River project 320
  - San Joaquin Valley 122, 229, 262-263, 267-268, 269-270
  - South Fork Canyon crossing 283
  - Springfield aqueduct 229
  - Stanislaus River project 308
  - Stronger than wrought iron 229
  - Tuberculation 229
  - Visitacion Valley 296
  - Withstanding of rust 229
- Steel pipe lines 155
- Steel siphons—
  - Alameda Creek Valley 258

Page

Steel siphons—
  New York water supply 229
  Hetch Hetchy aqueduct 264
  Los Angeles aqueduct 230-234
Steep gradient lessens cost of Hetch Hetchy aqueduct 155
Stillwater Creek Valley 333
Stimulus of cheap electric power 187
Stipulations, Garfield permit 149-150
Stock, capital, Spring Valley Water Company 385
Stock-raising, Feather River watershed 347
Stone—
  Cost of 243, 288
  Hetch Hetchy dam 287-288
  Proportion of in concrete 287-288
Stoney Creek 328
Storage—
  Alameda Creek gravels 188, 196-197
  Destroys organisms and impurities 32, 36-38, 53-54, 348
  Feather River project 349
  In foothills 58, 307
  Mokelumne River 366-367
  Niles Cone 70
  Pleasanton Valley gravels 198
  Poopenaut Meadow 58
  Possibilities 303-304, 366-367
  Purifies water 32, 36-38, 53-54, 348-349
  Rancheria Creek 58
  Reserves for bay region 68, 383
  Reservoirs
    20, 28, 127, 131, 147, 172-173, 177, 187, 303-304, 307-308, 366
  Stanislaus River 303-304, 307
  Vernon Lake 58
Storage capacity—
  (See "Capacity")
Storm waters—
  Coyote River 206-209
  Santa Clara Valley 208
Straining bugs and algae from surface waters 61
Strata—
  Dip of 110
  Livermore Valley refill 200
Stratification, Livermore Valley 89-90
Stratum of gravel underlying Santa Clara Valley 206
Strawberry—
  Creek 304
  Dam 304, 306
  Farm, near Niles 92-93
  Reservoir 304, 306
Stream flow—
  Diminution in 205
  Feather River 348
  Fluctuations in 188
  Intercepting of 205
  Stanislaus River, equalization of 305
  Tapping of 205
Streams, drying up of 209
Streets, San Francisco, with no mains for fire protection 219-220
Strength, steel pipe 229
Stronachlagher Hotel 49
Structural steel work, cost of painting 233
Structures, Hetch Hetchy project—
  Alternative distribution aqueducts 294
  Antonio-Valle Division 259-260
  Calaveras-Antonio Division 258-259
  Canyon Division 284, 286
  Crystal Springs-Irvington Division 252-254
  Eleanor-Cherry Division 289
  Hetch Hetchy Division 286-288
  Irvington-Calaveras Division 254-255, 258
  Irvington-Chabot Division 291
  Millbrae-San Mateo Division 297
  Not injured by earthquakes 126-127
  Poopenaut Division 291
  San Miguel-Millbrae Division 295-296
  Valle-Moccasin Division 260-281

Page

Studies—
  By C. D. Marx 78
  Hetch Hetchy aqueduct location 262-265 271-275
  Moccasin Creek crossing location 280
  Poopenaut dam 293
  Preliminary scope of 71
  Present sources of supply 81-82
  Roads 72
  San Joaquin River crossing 266-268
Subdivision—
  Movement towards 77
  Of great individual land holdings 77
  Of water among the different communities 21
Sub-irrigated lands—
  American River 311
  Cosumnes River 311
  Modesto and Turlock Districts 357
Submerged pipe—
  Alameda pipe line 383, 389
  Bay head crossing 253
  Dumbarton Straits 123
  Hetch Hetchy aqueduct 20
  Laying of 123
  McCloud River project 328, 337-338
  Mt. Shasta aqueduct 328
  Newark Slough 253
  Repairs to 127
  Sacramento River project 321-322
  San Joaquin River crossing 114, 122, 269-270
  San Joaquin River project 321-322
  Stanislaus River project 308
Subsidiary companies, Spring Valley Water Company 385
Sub-strata—
  Limitations of 192
  Of rock in tunnels 71
Subsurface flow—
  Coyote River 206, 208-209
  Coyote Valley gravels 207
Subterranean channels underlying Santa Clara Valley 207
Subterranean reservoir—
  Alameda Creek gravels 198
  Availability uncertain 188
  Intake to 196
  Livermore Valley gravels 188
  Montana 198
  Pleasanton Valley gravels 86, 188
  Rate of giving up of water 201
  Sunol gravels 188
  Texas 198
  Uncertainty of extent 188
Suburban communities, growth of 78
Sudbury reservoir 42, 53
Sudden floods, Alameda Creek 87
Suffering from inadequate water supply, San Francisco 211-220
Suisun—
  Cement works 242
  Marshes, reclamation of 328
  Point reservoir 328
Summer flow—
  Alameda Creek 86
  Feather River 347
Summer population, McCloud River 331, 335
Summit tunnels, yield 177
Sunlight exposure to; purification by 38
Sunnyside District—
  Inadequacy of water supply 220
  No mains for fire protection 219
Sunol—
  Discharge at 198
  Filters 197, 201, 383
  Ground waters 61
  Rainfall 193, 195
  Run-off 195-196, 198
  Water 201
  Watershed 196
Sunol dam—
  Area tributary to 196

Page

- Sunol dam—
  - Section, 184
  - Views, 184-185
  - Waste over, 193
- Sunol gravels—
  - Area of, 197
  - Beds, 389
  - Bottom of, 197
  - Dip in, 259
  - Draining of, 86
  - Erosion, 259
  - Priority, 197, 259
  - Saturation, 259
  - Yielding capacity, 81
- Sunol Valley—
  - Area of, 186
  - Gravels, 197, 259
  - Turbidity of streams through, 201
  - Yield of, 186
- Sunset District—
  - Inadequate water supply, 211, 218
  - View, 218
- Sunset reservoir, 131
- Superimposed lands, rights of owners of, superior to those of appropriators, 208-209
- Superintendent of Park, regulations by, 55
- Superiority, underground waters for irrigation, 209
- Supervision, catchment areas, Upper Tuolumne River, 13, 36, 38, 55
- Supervisors, Board of—
  - Complaints of inadequate water service, 213-218
  - Conferences with, 70
- Supreme Court decisions—
  - On ground waters, 97, 175
  - On use of percolating waters, 205-210
- Surface—
  - Areas, San Joaquin pipe, 233
  - Exposure, Alameda Creek gravels, 197
  - Flow, Alameda Creek, 188
  - Of roads, 15
  - East bay region, 173
- Surface waters—
  - Consumption of, bay region, 312
  - East bay region, 172, 176-177
  - Peninsula, 61
  - Screening of, 61
- Surge—
  - Pipe, San Joaquin siphon, 276
  - Shafts, 29-30
- Surge tanks—
  - Basis of estimates on, 251
  - Power house No. 2, 284, 286
  - San Joaquin Valley, 265
- Surplus capacity—
  - Hetch Hetchy aqueduct, 21, 34
  - Los Angeles aqueduct, 21
  - Manson plan, 143-144
- Surplus flood waters—
  - From Hetch Hetchy, conserving at Poopenaut Valley, 291
  - Tuolumne River, 58
- Surplus flow—
  - Available for irrigation, 21, 34, 124
  - Calaveras Creek, 97
  - Coyote River, 209
  - La Grange, 101-103
  - Mokelumne River, 365
  - Stanislaus River, 307
  - Tuolumne River, 81, 101-103
- Surveys—
  - Additional, after favorable decision from Washington, 160
  - Alameda Creek watershed, 188
  - By D. P. Doak on McCloud River project, 333
  - By C. E. Grunsky, 108
  - By Wm. Ham Hall, 108
  - By W. C. Hammatt, 109
  - By Sierra Blue Lakes Water and Power Company, 370
  - For Early Intake, 109
  - For perfecting details of plans, 71

Page

- Surveys—
  - For power house No. 1, 109
  - For power house sites, 108
  - For roads, 72
  - Hetch Hetchy, time advisable to begin, 179
  - In 1901, 108
  - In 1902, 108
  - In 1912, 108
  - McCloud River project, 343
  - Past, reasons why so crude, 72
  - San Miguel reservoir, 129-132
  - Slow progress of, 72
  - Time for beginning, 75, 179
  - Tuolumne River supply, 70
- Sutkamp, A. P., complaint of inadequate water supply, 218
- Sutro Heights Improvement Club, complaint of inadequate water service, 214
- Swamp lands—
  - Fertility of, 77
  - Hetch Hetchy Valley, 56
  - Owens Valley, 199
  - Pleasanton, 199
  - Reclamation of, 77
  - Sacramento River, 77
  - San Joaquin River, 77, 266-268
  - Yolo Basin, 317
- Swamps formed by excessive irrigation, 358
- Swanitz, H. W., survey of Poopenaut Valley, 292-293
- Swelling ground, 228
- Synclines, 110

- Table Mountain tunnel, 350
- Tailrace, 29
- Tapping of stream flow, 205
- Taxation, municipal water districts, 171
- Taxes—
  - Reduction of, 166
  - Spring Valley Water Company, 385
- Taylor, Col., 7
- Telephone lines, Hetch Hetchy project, 13, 15, 286
- Temescal reservoir, 172, 177
- Temperature—
  - Arroyo Valle reservoir, 84
  - Calaveras reservoir, 84
  - Effect on evaporation, 100
  - Effect on growths, 304
  - Effect on run-off, 194
  - Fall of, 100
  - High altitudes, 199
  - Livermore Valley, 199
  - Modesto and Turlock Districts, 358
  - Owens Valley, 199
  - Recording of, 100
  - San Antonio reservoir, 84
  - Wachusett reservoir, 36
- Temporary—
  - Branch works to utilize Calaveras storage, 255, 258
  - Buildings, Hetch Hetchy, 286
  - Buildings, Poopenaut camp, 291
  - Dam, Cherry Valley, 25-26
  - Dam, Eleanor Lake, 23, 25, 27
  - Dam, Hetch Hetchy, 73
  - Dam, Poopenaut Valley, 291
  - Diversion dam, 22
  - Power for construction, 73
  - Power plant, 73
  - Railroad for construction, 74, 290
  - Works at Hetch Hetchy dam, 287
- Terminal works, Irvington—
  - Gatehouse, 20, 123, 252-253
  - Reservoir, 252
- Tesla coal mines, 110, 221, 228
- Tesla railroad, 110, 113-114
- Tesla tunnel—
  - Cost of, 265, 269
  - Diameter, 244, 247, 260, 264, 281
  - Difficulties in construction, 283

INDEX

Page

- Tesla tunnel—
  - Formations 244, 247, 264-265
  - Length 247
  - Plans 280
  - Unit costs 244, 247, 265, 269, 283
- Test—
  - Case in courts, Niles Cone ground waters 70
  - Pits, Hetch Hetchy project 70, 71, 75
  - Wells, Brooklyn, N. Y. 70
  - Wells, Niles Cone 70
  - Wells, Santa Clara Valley 208
- Testing—
  - Joints, Hetch Hetchy pipe 232
  - Of altitude 108
- Texas, subterranean storage 198
- Thirlmere Lake 46-47, 53-54
- Thoms Creek 332
- Three-Mile Slough 315
- Tides—
  - Carquinez Straits 350-351
  - Ravenswood 254
  - Sacramento River 317
  - San Joaquin River 317
- Tilltill Valley—
  - Branch road to 15, 23, 290
  - Location of 117
  - View of 23
- Timbered areas—
  - Feather River watershed 347
  - McCloud River watershed 336
- Timber from public lands for construction work 15, 22
- Timbering—
  - Costs 224-225 244-252
  - Elizabeth tunnel 223, 226
  - Hetch Hetchy aqueduct tunnels 71, 120, 244-249, 252-253, 255, 258, 260, 265, 278, 283, 286, 297
  - Irvington gatehouse 255
  - Klamath project tunnels 250
  - Los Angeles aqueduct tunnels 224-225
  - Orphan asylum tunnel 251
  - Potrero tunnel 251
  - Shafts 265, 269, 284
  - Southern Pacific Railroad tunnels 250-251
  - Western Pacific Railroad tunnels 251
- Time required for construction work, Hetch Hetchy project 73-74
- Time to begin—
  - Borings 75
  - Calaveras reservoir construction 179
  - Further investigations 75
  - Hetch Hetchy aqueduct 179
  - Scenic road 74
  - Sinking of test pits 75
  - Surveys 75, 179
- Tipping up of gravels 190
- Titicus reservoir 14
- Title—
  - Desired by City to ground beneath scenic road 15
  - McCloud River water rights 328-329
  - To dam site, floor and shores, Hetch Hetchy Valley 13
  - To land near Early Intake 22
  - To lands, Hetch Hetchy, desired by City 13, 15
- Todd, J. O., rain gauging, Lake Eleanor 101
- Tomatoes, irrigation of 92
- Topographical maps—
  - Alameda Creek bed 182
  - San Joaquin Valley 108
  - U. S. Geological Survey 108, 239
  - Yosemite quadrangle 108
- Topography—
  - Foothills east of San Joaquin Valley 271-275
  - Hetch Hetchy aqueduct line 221, 261-263, 266-268, 271-275, 277, 280, 282
  - Mokelumne River region 365
  - Mt. Shasta aqueduct 328
  - Niles Canyon 84
  - Pleasanton Valey 86
- Topography—
  - San Francisco 211, 383
  - San Joaquin Valley 108, 261-263, 266-268
  - Tuolumne River Canyon 277, 282
- Torrential floods—
  - Alameda Creek 85, 180, 188, 193
  - Livermore Valley 188-190, 197
  - Pleasanton Valley 188-190, 197
- Toughness, steel pipe 229
- Tourists
  - Boston reservoirs 35
  - Exclusion of 33, 52
  - Hetch Hetchy 33, 148
  - On roads around reservoirs 43, 46-51, 54
- Towns, McCloud River watershed 335
- Toyne, G., complaint of inadequate water supply 216
- Traffic to Hetch Hetchy mainly through Chinese Camp 289
- Trail—
  - Built by D. P. Doak 339
  - Hog Ranch to Hetch Hetchy 289
  - Construction for Hetch Hetchy project 298
- Transformers, power house No. 2 282
- Transmission lines—
  - Hetch Hetchy project 15, 31, 73
  - Los Angeles aqueduct 227
  - McCloud River project 328
  - Mokelumne River project 368-369, 371-372
- Transmission of power, Grunsky plan 141
- Transparency of water 201
- Transpiration of moisture in high altitudes 100
- Transportation—
  - Charges 298
  - Costs, Hetch Hetchy divisions 241-242, 300-301
  - Difficulties of 119
  - Facilities 166
  - Of construction materials 13, 15
- Treacherous ground—
  - Chabot tunnel 249
  - Dry Creek tunnel 276
  - Los Angeles aqueduct tunnels 225
- Treatment of river waters 317, 348
- Trenches—
  - San Joaquin pipe line 229-230, 269
  - San Joaquin River crossing 270
- Trestles—
  - Bay head pipe 253
  - Elimination of, Freeman plan 142
  - Grunsky plan 139
  - Manson plan 139
  - San Joaquin River crossing 269-270
  - Stanislaus River project 308
- Trial location line—
  - For steel pipe, San Joaquin Valley 262-263, 267-268
  - For tunnels, Hetch Hetchy aqueduct 261
- Tributaries—
  - Alameda Creek 188
  - McCloud River 334
  - Stanislaus River 303-304
- Truckee-Carson project tunnels 250
- Truck gardening—
  - Niles Cone 92-94
  - Surplus water available for 21
- Tuberculation, steel pipe 229
- Tulloch, Mr., rights owned by 307
- Tunnel—
  - Cost cheapened by paying bonuses 226
  - Grade, San Joaquin Valley 265
  - Lining, thickness of 242
  - Near Knight's Ferry 276
  - Near San Mateo 123
  - On peninsula 123
  - To Lake Chabot 125
  - Under bay 321
  - Under Lake Eleanor 25, 27
- Tunnel capacity—
  - American-Cosumnes project 313
  - Grunsky plan 140

Page

- Tunnel capacity—
  - Larger capacity costs relatively little more ... 140
  - Stanislaus River project ... 308
- Tunnel construction—
  - Grunsky plan ... 140
  - Hetch Hetchy aqueduct ... 121
- Tunneling—
  - Character of rocks ... 111
  - Conditions for ... 221
  - Hetch Hetchy aqueduct ... 221
  - Rock formation ... 71
- Tunnels—
  - Alternative distribution aqueducts ... 125-126
  - Costs ... 242-243, 250-251
  - Depth of ... 111
  - Diameter of ... 122
  - Formula for computing carrying capacity ... 221
  - Freeman plan of development ... 139-140
  - Grunsky plan of development ... 139-140
  - Hetch Hetchy aqueduct ... 11, 20-21, 121-122, 221-228, 243-249, 261
  - Hydraulic elements ... 120
  - Hydraulic gradient of ... 122
  - Klamath project ... 250
  - Lincoln Mine ... 250
  - Lining of ... 21, 120
  - Los Angeles aqueduct ... 128, 223-227
  - Manson plan of development ... 139
  - Mokelumne River project ... 369, 372
  - Peninsula pipe line ... 294
  - Reconnoitering line of ... 109-110
  - Retarding effect of moss-like growth ... 221
  - Rocks to be encountered ... 111
  - Roughness of finish ... 221
  - Route of ... 112-116
  - Sacramento River project ... 320-321
  - Salt River project ... 250
  - San Joaquin River project ... 320-321
  - Santa Ana Canal ... 250
  - Shoshone project ... 250
  - Slope of ... 112-117
  - Southern Pacific Railroad ... 250-251
  - Stanislaus River project ... 308
  - Sub-strata of rock in ... 71
  - Surplus carrying capacity ... 34
  - Timbering of ... 71, 120, 224-225, 246-249
  - Truckee-Carson project ... 250
  - Unit costs ... 224-225, 243-251
  - Western Pacific Railroad ... 251
  - Yakima project ... 250
  - Yuba River project ... 356
- Tuolumne—
  - County Water Company ... 304-305
  - Diversion canal ... 139
  - Drainage basin, Stanislaus water used in ... 305
  - Main canal ... 139
  - Meadows ... 59
- Tuolumne River—
  - Canyon ... 264, 277, 282, 284
  - Canyon crossing ... 278-279
  - Catchment areas ... 8, 24
  - Discharge ... 101-103, 373
  - Flood waters ... 58
  - Gaugings ... 101-103
  - Line of flow ... 114-117
  - Map of ... 4
  - Natural flow of ... 285
  - Prior rights on ... 8
  - Proximity ... 158-160
  - Rating table ... 373
  - Reservoir sites ... 58
  - Run-off ... 98-99, 101-103, 105
  - Surplus waters ... 58
  - Tables of run-off ... 374-376
  - Waste waters ... 58
  - Water ... 53-57, 151, 153, 284. 316-317
  - Watershed ... 102, 374

Page

- Tuolumne River—
  - Yielding capacity ... 8, 101-103, 104. 106-107
- Tuolumne River project—
  - Advantages of ... 72-73, 156-157
  - Comparisons with other sources ... 151-1601
  - Concentration of further study on ... 75
  - Cost estimates ... 160n-160p
  - Quantity of water available to City ... 101-103, 106-107
- Tuolumne water supply—
  - Adequacy of ... 80-81
  - Joint use by bay cities ... 161-165
  - Management of ... 299
- Turbidity—
  - Feather River water ... 347
  - Flood waters ... 200
  - Pleasanton water ... 201
  - Sacramento River water ... 317
  - San Joaquin River water ... 317
  - San Leandro reservoir ... 134
  - Stanislaus water ... 309
  - Sunol Valley streams ... 201
  - Tuolumne River water ... 284
- Turbid waters, filtration of ... 88
- Turlock Irrigation District—
  - Area irrigated ... 359
  - Cost of system ... 360
  - Diversion by ... 100
  - Excessive use of water ... 83
  - Joining with Modesto District ... 305
  - Needs of ... 21, 82-83, 357
  - Percentage of land irrigated ... 359
  - Prior right of ... 83, 103, 106-107, 285
  - Quantity of water put to beneficial use ... 104
  - Report by J. H. Dockweiler ... 82-83, 357-363
  - Reservoirs planned by ... 83
- Turnouts, wagon road ... 13
- Twin Peaks Association of Improvement Clubs, complaint of inadequate water supply ... 216
- Twin Lakes ... 160a, 310
- Two Mile Bar ... 307
- Type—
  - Los Angeles pipe ... 230
  - Of construction, Hetch Hetchy scenic road ... 19
  - Of construction. McCloud River project ... 330
  - Steel pipe, San Joaquin Valley ... 229
- Typhoid—
  - Germs ... 343
  - Risk of ... 37
- Typical complaints of inadequate water service, San Francisco ... 213-217

- Unabsorbed portion, flood flows, Alameda Creek ... 198
- Unalienable rights to unappropriated water of Tuolumne River to be reserved to bay cities ... 22
- Unappropriated waters—
  - Cherry Valley dam site ... 28
  - Eleanor Lake dam site ... 28
  - Of Tuolumne River to be reserved for bay cities ... 22
- Unattractive water, Lake Merced ... 62
- Uncertainty—
  - Of data, water companies ... 82
  - Of seasons, California ... 209
  - Spring Valley records, Alameda Creek discharge ... 180
- Underbrush—
  - Alameda Creek ... 182-183
  - Retarding effect of ... 82
- Underground—
  - Channels, Santa Clara Valley ... 207
  - Reservoir ... 80-81, 94, 201
  - Storage, Alameda Creek ... 85-86
- Underground waters—
  - Diversion of for outside use ... 205
  - Niles Cone ... 69-70
  - Owens Valley ... 202
  - Right of landowner to ... 208
  - Superiority of, for irrigation ... 209

INDEX

Page

Underground waters—
  Supreme Court decisions ... 97
Underlying strata, Santa Clara Valley ... 206, 208
Undesirable conditions, Crystal Springs reservoir ... 62
Undesirability of foothill reservoirs ... 307
Unfavorable conditions—
  Alameda Creek gaugings ... 181-183
  Cherry dam site ... 28
  Eleanor Lake dam site ... 28
Uninhabited catchment areas ... 32-33, 53
Union reservoir ... 304-306
Union Water Company—
  Additional supply available ... 80
  Rights claimed on Calaveras ... 190
  System of ... 177-178
  Water rights of ... 96, 190
Unit costs—
  Alameda Creek siphon ... 258, 291
  Antioch filter tunnels ... 228
  Antonio-Valle Division ... 259-260
  Bay head pipe ... 236-237, 253-254
  Buriburi tunnel ... 296
  Calaveras-Antonio Division ... 258-259
  Canyon tunnel ... 249, 286
  Chabot tunnel ... 241, 291
  Corbett tunnel, Shoshone project ... 250
  Crystal Springs by-pass ... 298
  Crystal Springs-Irvington Division ... 252-254
  Dove Creek pipe line ... 230
  Dry Creek crossing ... 248, 278
  Dry Creek tunnel ... 278
  Early Intake dam ... 284
  Eleanor-Cherry Division ... 289
  Eleanor-Cherry tunnel ... 289
  Elizabeth tunnel ... 223, 226
  Grading ... 251
  Groveland tunnel ... 249, 283-284
  Hetch Hetchy aqueduct tunnels ... 243-249
  Hetch Hetchy dam ... 287-288
  Hetch Hetchy reservoir site clearing ... 286
  Huntley tunnel ... 250
  Irvington-Calaveras Division ... 254-255, 258
  Irvington-Chabot Division ... 291
  Klamath project tunnels ... 250
  Lincoln Mine tunnels ... 250
  Los Angeles aqueduct tunnels ... 224-225
  Los Angeles steel pipe siphons ... 230
  Lumber ... 251
  Manson's estimates, too low ... 143
  Mission Pass tunnel ... 248, 281
  Moccasin Peak tunnel ... 248, 281
  Oakdale Irrigation District's tunnels ... 223
  Portland aqueduct pipe ... 237
  Potrero tunnel ... 296
  Redwood tunnel ... 244, 246, 252-253
  Salt River project, Arizona ... 250
  San Andreas tunnel ... 297
  San Antonio pipe line ... 230
  San Antonio tunnel ... 246, 258
  San Bruno tunnel ... 295
  San Joaquin pipe line ... 231-235
  San Lorenzo Creek siphon ... 291
  San Miguel-Millbrae Division ... 295-296
  Southern Pacific tunnels ... 250-251
  South Fork Canyon crossing ... 283
  Tesla tunnel ... 247, 265, 269, 283
  Truckee-Carson project tunnels ... 250
  Tunnels through various formations ... 255, 258, 260, 265, 278, 281, 283, 291
  Valle-Moccasin Division ... 264-265, 269,-270
  Valle tunnel ... 247, 260
  Western Pacific Railroad tunnels ... 251
  Yakima project tunnel ... 250
United Properties Company, water rights of ... 96, 179
United States—
  Coast Survey, charts of San Francisco Bay ... 127, 321
  Fish hatchery, McCloud River ... 334, 336

Page

United States
  Government, exchange of lands with ... 152
  Lands, taking of building materials from ... 15
  Ownership in Hetch Hetchy Valley ... 13
  Reclamation Service, tunnels for on irrigation projects ... 250
United States Department of Agriculture
  Irrigation, Modesto and Turlock Districts ... 358
  Irrigation, Santa Clara County ... 78
  Soil survey, Livermore ... 85
United States Geological Survey
  Alameda Creek flow ... 85
  Contour maps ... 108
  Feather River gaugings ... 348
  Geologic folios ... 109-110
  McCloud River gaugings ... 329, 334, 339-340
  Mokelumne River discharge ... 365
  Niles Canyon gaugings ... 83-84
  Sacramento River water analyses ... 317
  San Joaquin River water analyses ... 317
  Stanislaus River flow ... 307
  Topographic maps ... 239
  Tuolumne River gaugings ... 98
  Yuba River gaugings ... 355
Uniting of San Francisco Bay cities in water district ... 9
University Mound District, inadequate water supply ... 220
University Mound reservoir ... 131, 212, 294, 296, 389
Unloading pipe, cost of ... 230-231, 236
Unpopulated watershed, Hetch Hetchy ... 344
Unskilled laborers, wages in California ... 251
Untimbered tunnels, comparison on cost with timbered tunnels ... 342-343, 245
Unutilized water from Tuolumne will be diverted by City ... 53
Upper Strawberry reservoir ... 304
Upper Tuolumne River, comparisons with other sources ... 151-1601
Urban communities, growth in ... 78
Urgent demand for water ... 175
Use—
  Artesian waters ... 205
  Hetch Hetchy preserving other camp sites ... 58
  Labor-saving appliances for laying pipe lines ... 231
  Percolating waters ... 205-210
  Roads, Hetch Hetchy, by public ... 13, 15
  Steel pipe permitting cheapest structural methods ... 229
  Surplus capacity of Hetch Hetchy aqueduct for irrigation ... 21
Use of water—
  Deprivation of ... 205
  Domestic ... 21
  From Stanislaus River in Tuolumne basin ... 304-305
  Increase in ... 79
  Industrial ... 176
  Irrigation ... 21
  Municipal ... 21
Utica—
  Canal ... 305
  Dam ... 306
  Ditch ... 305
  Flume ... 305
  Mining Company ... 304-306
  Reservoir ... 304-306
Utilization of fall—
  Early Intake ... 282
  Eel River ... 346
  Feather River project ... 350
  Hetch Hetchy to Early Intake ... 284
  McCloud River ... 327, 331
  Stanislaus River ... 305
  Tesla tunnel ... 281

Vagaries of rainfall ... 194-195, 199
Vagueness of records, water companies ... 82
Valle-Moccasin Division—
  Cost ... 281, 300
  Description ... 241, 260
  Length ... 241, 260, 264
  Structures on ... 260-281

Page

- Valle-Moccasin Division—
  - Unit costs, 260, 264-265, 269-270, 278-279, 281
- Valle tunnel—
  - Cost, 260
  - Depth below surface, 264
  - Diameter, 247, 259
  - Formations, 247, 259-260
  - Length of, 247, 259
  - Percentage timbered, 247, 260
  - Shafts, 265, 269
  - Unit costs, 247, 260
- Vallecito, 303
- Vallejo Mill, 385
- Valley rainfall, ratios of mountain run-off to, 105
- Valleys—
  - Subdivision into irrigated farms, 77
  - Stanislaus River, 303
  - Tributary to San Francisco district, 77
- Value—
  - Bay Cities Water Company's properties, 313
  - Of hardness in public water supply, 317
  - Of the power asset, 31-32
  - Spring Valley Water Works, 394
- Valves, Hetch Hetchy aqueduct, 20
- Vancouver, growth of, 78
- Vapor laden winds—
  - Coast Range, 193
  - Mt. Hamilton, 88
- Variability of rainfall, bay region, 383
- Variance in records, Alameda Creek yield, 193
- Variation—
  - In flow, McCloud River, 334
  - In run-off, 199
- Variety of formations, Los Angeles aqueduct, 225-226
- Varying—
  - Depth to water, wells, Santa Clara Valley, 208
  - Rainfall in California, 209
- Vastness—
  - Coyote Valley gravel beds, 207-209
  - Santa Clara Valley gravel beds, 207-208
- Vegetation—
  - Lake Merced, 62
  - Surface waters in California, 62
  - Varying character of, 199
- Velocities, Hetch Hetchy aqueduct tunnels, 221
- Velocity—
  - Alameda Creek flow, 182, 185
  - Approach of water, Niles and Sunol dams, 182, 185
  - Arroyo Mocho flow, 201
  - Arroyo Valle flow, 201
  - McCloud River, 335
  - Movement of gravels, 198
  - Water in Hetch Hetchy tunnels, 121
- Verdure, high altitudes, 100
- Vernalis Farming Company, buildings of, 267, 269
- Vernon Lake—
  - As reserve supply, 58
  - Catchment area, 100
  - City desires to secure rights to, 58
  - Dam at, 58
  - Flow from, 16
  - Location of, 117
  - Power plant at outlet of, 160r
  - Reservoir at, 28
  - Road to, 23
- Vertical cleavage, planes, 276
- Vested rights—
  - American River, 312
  - Cosumnes River, 312
  - Mokelumne River, 366, 370-371
  - Stanislaus River, 304-305
  - Tuolumne River, 82-83, 101
- Views—
  - Alameda Creek, 182-185, 203
  - Alfalfa irrigation, Gregory Ranch, Decoto, 93
  - Bart Brown well, Arden, 93
  - Boston reservoirs, 35, 37, 39, 40-42

Page

- Views—
  - Buena Vista District, 216
  - California Nursery Company, irrigating scenes, 92-93
  - Castro Valley dike, site, 135-136
  - Chabot Lake, 66
  - Chestnut Hill reservoir, 40-41
  - Craig Goch dam, 51
  - Croton reservoir, 42-43
  - Decoto, 92-93
  - Eleanor Lake, 23
  - Fairmount District, 217
  - Hetch Hetchy dam site, 8
  - Hetch Hetchy reservoir, 6, 10, 12
  - Hetch Hetchy scenic road, 10
  - Hetch Hetchy Valley, 6, 8, 10, 12 57
  - Irrigating tomatoes, Bell Ranch, Decoto, 92
  - Loch Katrine, 48-50
  - Mahopac Lake, 45
  - Middlesex Fells reservoir, 35, 37, 39
  - Niles, 92-93
  - Niles Cone, 203
  - Niles Cone wells, 92-93
  - Niles dam, 182-183
  - North Beach District, 215
  - Norwegian roads, 14, 17-18
  - Ocean View District, 217-218
  - Oifjord Lake, Norway, 17-18
  - Parkside, 218
  - Richmond District, 213-214
  - Road along Oifjord Lake, Norway, 17-18
  - Roads in Norway, 14, 17
  - San Francisco, streets in, 213-218
  - San Leandro dam, 66
  - San Miguel reservoir, 130, 133
  - Scenic road, Hetch Hetchy, 16-17, 19
  - Strawberry farm, Niles, 92-93
  - Sudbury reservoir, 42
  - Sunol dam, 184-185
  - Sunset District, 218
  - Thirlmere Lake, 46-47
  - Tilltill Valley, 23
  - Titicus reservoir, 14
  - Tuolumne Meadows, 59
  - Vyrnwy reservoir, 50
  - Wachusett dam, 35
  - Wapama Falls, 16
  - Wells on Niles Cone, 92-93
  - Western Addition, 215
- Villages on catchment areas, 35-36, 54, 303
- Virulence of germs lost by storage, 37
- Visitacion Valley pipe line, 296
- Visitors to Hetch Hetchy, 148
- Voids, sands and gravels, Livermore Valley, 199
- Volcanic ash deposits, 196
- Volume—
  - Of flow, 201
  - Pore space, Livermore Valley gravels, 201
  - Storm waters, Coyote Creek, 209
- Von Geldern, report by, 187
- Von Schmidt, A. W., 386
- Vyrnwy reservoir, 50

- Wachusett—
  - Aqueduct, 145
  - Dam, 35
  - Reservoir, 36, 53
- Wages—
  - Basis for Hetch Hetchy estimates, 251
  - Common labor, 251-252
  - Effect of political interests, 251
  - High prevailing rate of, 77
  - Liberal in San Francisco, 79
  - Los Angeles aqueduct tunnels, 223
  - Oakdale Irrigation District, 251
- Wagon haulage—
  - Rate for cement, 242
  - Rates, Sierra region, 242

INDEX

Page

- Wagon haulage—
  - Steel pipe, Los Angeles aqueduct... 230-231
- Wagon roads, Hetch Hetchy project—
  - Branching from scenic road... 15
  - Hetch Hetchy to Cherry Valley... 28-29
  - Hetch Hetchy to Eleanor Creek... 28-29
  - Hetch Hetchy to Poopenaut Valley... 293
  - Length of ... 13
  - Maintenance of ... 13
  - None at present... 29
  - Turnouts on ... 13
- Wales, reservoirs in... 48, 51
- Wapama Falls—
  - Replenishment by dam at Vernon Lake... 58
  - Scenic road to ... 290
  - View of ... 16
- Washington and Murray Township Water Company... 385
- Washington, D. C.—
  - Berkeley representation at on Hetch Hetchy... 161
  - Consumption per capita... 79
  - Oakland represented at on Hetch Hetchy... 162
- Waste of water, Modesto and Turlock Districts... 358
- Waste waters—
  - Alameda Creek ... 188, 193
  - Coyote River ... 208-209
  - Croton dam ... 187
  - Hetch Hetchy, caught at Poopenaut dam... 293
  - La Grange ...101-103, 360
  - Niles Canyon ... 85-86
  - Sunol dam ... 193
  - Tuolumne River ... 58
- Water—
  - Board, Hetch Hetchy water supply... 299
  - Carrying capacity, Hetch Hetchy aqueduct tunnels... 221-222
  - Chute, Tesla tunnel... 283
  - Contours, Niles Cone... 95
  - For lawns and gardens... 79
  - Gauging apparatus at each reservoir... 33
  - Hammer, strain due to... 229
  - Locations, McCloud River...329, 338-339
  - Measurement ... 33
  - Sorting of material... 202
  - Storage capacity, cones... 175
- Water bearing strata—
  - Coyote River ... 206
  - Livermore Valley ... 200
  - Sections of ... 89-90
  - Signs of ... 109
  - Wells, Alameda Creek... 192
- Water borne—
  - Diseases ...33, 36-37, 42
  - Germs ... 37, 42
- Water companies—
  - Acquired by Spring Valley Water Company... 384
  - Consolidated into Peoples Water Company... 177
  - East bay region... 174
  - Over-estimated extent of their undeveloped resources... 69-70
  - Records not dependable... 82
- Water control during construction—
  - Hetch Hetchy dam... 287
  - Poopenaut dam ... 291
- Water districts—
  - Act governing incorporation of...164-165, 167-171
  - Metropolitan ... 63-64
  - San Francisco Bay cities...9, 161-165
- Water duty—
  - Livermore Valley ... 85
  - Modesto Irrigation District ... 85
  - Pleasanton Valley ... 85
- Water famine—
  - Danger of ... 127
  - Peninsula, threatened by boring Ravenswood wells... 391-392
  - Reserve against ... 65
- Water level—
  - Cherry River mouth... 109
  - Durham Bridge ... 266
  - Early Intake ... 109, 282

Page

- Water level—
  - Hetch Hetchy dam... 285
  - Hetch Hetchy reservoir... 11
  - McMullin Lake ... 266
  - Moffatt Bridge ... 108
  - Power house No. 1... 109
  - Priest's Hotel ... 109
  - Red Mountain Bar... 108
  - San Joaquin River... 266-268
  - South Fork mouth... 109
  - Tuolumne River ... 108-109
- Water plane—
  - Coyote Valley gravels... 207, 209
  - Santa Clara Valley gravels... 209
- Water power development—
  - Feather River ... 100
  - Hetch Hetchy aqueduct... 128
  - Los Angeles aqueduct... 128
  - Use of steel pipe for... 229
- Water power possibilities—
  - Hetch Hetchy aqueduct... 29-31
  - McCloud River ... 336
- Water pressure—
  - Fire hydrants, San Francisco...215, 218-219
  - Hetch Hetchy aqueduct... 121
  - Inadequacy of in San Francisco...213-214, 216-219
- Water rates—
  - Fixing of ... 170, 177
  - Metropolitan water district... 170
  - Peoples Water Company... 177
  - Spring Valley litigation... 393-394
- Water right purchases—
  - Cost for the several divisions of the Hetch Hetchy Aqueduct ... 300-301
  - For Stanislaus River project... 308
- Water rights—
  - Alameda Creek ... 96, 187
  - Arroyo Valle ... 96
  - Bay Cities Water Company...96, 179, 186
  - Bonita Creek ... 96
  - Calaveras Creek ... 187
  - Cherry Creek ... 72, 138
  - Diligent prosecution of work on... 341
  - Eleanor Creek ... 72, 138
  - Expenditures by San Francisco on... 72, 138
  - Isabel Creek ... 96
  - Law on ... 342
  - Legal questions ... 96
  - McCloud River ... 338-341
  - Mokelumne River ... 368, 370
  - Necessity to secure for future... 138
  - San Francisco's ... 72, 138
  - Sierra Blue Lakes Water and Power Company... 368, 370
  - Smith's Creek ... 96
  - Spring Valley Water Company... 384-385
  - Time after posting of notice for beginning of construction work on ... 341
  - Tuolumne River ... 72, 138
  - Union Water Company... 96
  - United Properties Company... 96, 179
- Water service areas, San Francisco... 212
- Water service, San Francisco—
  - Absence of in certain districts... 213-214
  - Inadequacy, San Francisco ... 145
  - Poor circulation ... 216
- Watersheds—
  - (See "Catchment areas")
- Water supply—
  - Inadequacy, bay cities ... 145
  - Inadequacy, San Francisco ... 145
  - Needs of San Francisco district... 80
  - Order of development... 62-75
  - Scale of new works for other cities... 145
- Water supply problem—
  - Change in conditions since Garfield permit was granted. 138
  - Los Angeles, solution of... 80, 138
  - New York, solution of... 138

Page

- Water supply problem—
  - San Francisco, solution of 80, 138
- Water table—
  - Fluctuating 358
  - Lowering of 91, 175, 186
  - Niles Cone 91, 95, 175, 204
  - Rise of 357
  - Slope of 94
- Weak points, Grunsky plan 142, 144
- Weedy water, Lake Merced 62
- Weight—
  - Bay head pipe 237
  - Hetch Hetchy pipe 236
  - San Joaquin pipe 235
- Weirs—
  - Alameda Creek 181
  - Drowning of 181
  - Gauging 33
  - Hetch Hetchy dam 285
  - Niles dam 181
- Well boring—
  - Livermore Valley 86, 89-90
  - Records by Cyril Williams, Jr. 202
- Well drillers' logs 86
- Wells—
  - Alameda City 174
  - Alvarado 177
  - Bay shore 82
  - Bell Ranch, Decoto 92-93
  - Brackish through over-pumping 81
  - Brooklyn 70
  - Consumption of water from, bay region 312
  - Dried up 204
  - East bay region, draft on 174
  - Fitchburg 177
  - Hercules Water Company 178
  - Livermore Valley 86, 89, 90
  - Miller Ranch 206-208
  - Modesto and Turlock Districts 359
  - Niles Cone 70, 95, 177, 203-204
  - Output of 177
  - Overflow from 206-207
  - Owens Valley 202
  - Private 81, 174
  - Ravenswood 96
  - Richmond 177
  - Rising of water in 359
  - San Francisco 383
  - San Francisco bay shore 82
  - San Leandro Cone 177
  - San Lorenzo Cone 177
  - San Lorenzo Water Company 178
  - San Pablo Cone 176-177
  - Santa Clara Valley 208-209
  - Santa Fe Railroad Company 176
  - Standard Oil Company 176
  - Test 70
  - Union Water Company 177
  - West San Pablo Land and Water Company 178
- West Clay Park District, no mains for fire protection 220
- West End Improvement Club, complaint, inadequate water supply 218
- Western Addition, San Francisco—
  - Complaints of inadequate water supply 211, 214
  - Inadequate fire protection 211, 214
  - Views 215
- Western Pacific Railroad Company—
  - Contract prices for mountain work 251
  - Exploiting Feather River region 348
  - Tunnels built by 251
- West Richmond District, no mains for fire protection 220
- West San Pablo Land and Water Company 174, 178
- Wet seasons—
  - Alameda Creek 196
  - Coyote River 209
- Whipple on softness of water 153

Page

- Whiteness of water—
  - Alameda Creek 61, 194
  - Pleasanton 61
  - Sunol 61
- Wholesomeness of Spring Valley water 61
- Wide fluctuations in flow—
  - Alameda Creek 188
  - Control of 188
  - Niles Conyon 83
- Wild Cat wells 172, 177
- Williams, Cyril, Jr.—
  - Commendation for zeal in City's service 160s
  - Error detected in Spring Valley records 84
  - On run-off, Tuolumne River 101-103
  - Presentation of problem, Alameda Creek 190
  - Rainfall studies 197
  - Report on Alameda Creek yield 81, 186-187
  - Report on Livermore Valley 81
  - Thoroughness of investigations 187
  - Well borings, Livermore Valley 86
- Willingness to begin work on Hetch Hetchy dam 72
- Winchester Water Board 39
- Wind movement, recording of 100
- Winter—
  - Evaporation 199
  - Protection, concrete plant, Hetch Hetchy 287
- Wood, Andrew Y., commendation for zeal in City's service 160s
- Woodbridge Canal, area irrigated by 365
- Wood's Creek, grades 289
- Wood-stave pipe, Rough and Ready Creek mouth 260
- Work done by Sierra Blue Lakes Water and Power Company, to hold water rights 370
- Working points, Hetch Hetchy aqueduct within easy reach of railroads 289
- Working season, Hetch Hetchy region 73-74
- Wrought iron pipe—
  - Resistance to rust 229
  - San Francisco 384

- Yakima project tunnel 250
- Yardage—
  - Hetch Hetchy aqueduct tunnels 120
  - Hetch Hetchy dam 118, 285
  - Los Angeles aqueduct 224
  - Poopenaut dam 293
  - San Bruno tunnel 238
  - Tunnels 250-251
- Yield—
  - Above Pleasanton 186
  - Alameda Creek 83-84, 179-202, 391
  - Alvarado wells 177
  - American-Cosumnes source 312, 314
  - Bay shore wells 177
  - Berryman tunnel 177
  - Cherry Creek watershed 8, 104
  - Coast streams 392
  - East bay sources of supply 177
  - Eel River watershed 345
  - Eleanor Lake watershed 8, 104
  - Fitchburg wells 177
  - Hetch Hetchy watershed 8, 104
  - Livermore region 199
  - Merced Lake 126
  - Peninsula watersheds 388, 391
  - Peoples Water Company's sources 81
  - Pfieffer Springs 177
  - Piedmont Springs 177
  - Pleasanton wells 81
  - Present sources 80-81
  - Railroad Flat watershed 366
  - Richmond wells 177
  - San Leandro reservoir 177
  - San Pablo wells 177
  - Santa Clara Valley gravels 209
  - Shepard Canyon 177
  - Spring Valley Water Company's sources 81
  - Summit tunnels 177

INDEX

- Yield—
  - Sunol Valley gravels, 81, 186
  - Temescal watershed, 177
  - Tuolumne River, 8, 101-104, 106-107
  - Water plants, both sides of bay, over-estimated, 69-70
  - Wild Cat wells, 177
- Yolo Basin, 317
- Yosemite National Park—
  - Borings in, 71
  - Climate, 56
  - Regulations, 34, 54-55
- Yosemite quadrangle, 108
- Yosemite Valley, 148
- Yuba River—
  - Adequacy of supply, 355
  - Discharge, 355
  - Equalization of flow, 355
  - Gaugings, 355
  - Hotle project, 355
  - Priorities, 355
  - Watershed, 355
- Yuba River dam, wages paid on, 251
- Yuba River project—
  - Comparison with Sacramento River project, 355-356
  - Conditions presented by, 160L
  - Conduit, 356
  - Disadvantages of, 157, 160j
  - Diversion point, 356
  - Diverting dam, 356
  - Tunnels, 356
- Zones—
  - Fault, 109
  - Of bad ground, 111
  - Peoples Water Company, 177
  - San Francisco, 384